METEOROLOGICAL OFFICE

ANNUAL REPORT 1969

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ANNUAL REPORT
ON THE
METEOROLOGICAL OFFICE

1969

Presented by the Director-General
to the
Secretary of State for Defence

LONDON
HER MAJESTY'S STATIONERY OFFICE
1970

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Cover photograph by R. K. Pilsbury

FOREWORD BY THE DIRECTOR-GENERAL

During the past year, a number of important steps have been taken in implementing a programme of modernization that will equip the Meteorological Office to fulfil its future responsibilities, both national and international.

An order has been placed for an IBM System 360/Model 195 computer and associated equipment to be installed at Bracknell during 1971. The computer, one of the most powerful in the world and the largest machine available from IBM, will be used to exploit operationally in day-to-day forecasting the substantial advances which have been made in recent years, and which are confidently expected to lead to weather forecasts of greater reliability and range. In particular, the new computer should enable the Office to issue for the first time: more-detailed forecasts of the weather, including the amount and distribution of rainfall likely to occur over the British Isles and western Europe during the following 24–36 hours; and reliable if somewhat less-detailed forecasts of the weather to be expected for up to about a week ahead. The computer will also keep the Meteorological Office in the forefront of research into the evolution of weather systems ranging in size from that of an individual thunderstorm to the totality of systems that cover the entire global atmosphere.

Preparation of a weather forecast for a day or more ahead, even for an area as small as the British Isles, requires continually updated knowledge of current weather over a large area of the globe. To cope with the great flow of information, including that now becoming increasingly available from satellites, a new automated computer-controlled communications system is being installed at Bracknell. This includes a complex real-time switching system capable of handling high-speed transmission of meteorological data with built-in techniques for error detection and correction and routines for the compilation, editing, routeing and storage of messages. The first stages of the system, involving automation of the telecommunications centre at Bracknell, will enable us to fulfil our responsibilities as a Regional Telecommunications Hub on the global trunk circuit of the World Weather Watch and should be completed by the end of 1970. Later phases will be concerned with interfacing the communications system to the new giant computer in 1971 and the gradual automation of the whole national meteorological data-gathering network. An important component of the latter will be a new automated radiosonde system which has now reached an advanced stage. An order for 100 pre-production models has been placed; if these are satisfactory the first set of the new equipment should be installed in 1972 and the remaining 15 stations completed within a year or so thereafter. After several years of development and testing, an order is being placed for 10 automated weather stations which will be used for operational trials in various parts of the country.

Meanwhile, day-to-day demands for meteorological information and advice continue to grow unabated. The number of inquiries received from industry and the general public rose by 9 per cent to a new record of 1·61 million, while the number of forecasts for aviation increased marginally to 1·44 million. The number of calls on the automatic telephone weather service increased by 24 per cent to a record 12·4 million. During February the London Weather Centre

received 45 000 inquiries with more than 3000 on a single day. In periods of bad weather the pressure on some forecasting offices is overwhelming and the staff have the greatest difficulty in coping with the flood of inquiries. For this reason, the Office is investigating the possibility of finding other means of meeting the need for nation-wide, round-the-clock bulletins of weather information and forecasts. With the co-operation of the BBC, special warnings of snow, icy roads, fogs and strong winds have been broadcast on BBC Radio 2. On the other hand, despite strenuous representations from the Office, the time devoted to weather forecasts on television was further reduced and the service to the public suffered accordingly.

In the forecasting field, a number of modifications have been introduced into the operational numerical routines, which have produced improvements in the meteorological analyses and forecasts, including the forecasting of upper air temperatures for aviation. Important advances have been made in developing objective mathematical methods of three-dimensional analysis of meteorological fields. These techniques are now being extended to incorporate interpolation in time as well as in space, and this will be important for incorporating data at non-standard times and levels, such as observations of winds from aircraft and temperatures from orbiting satellites.

Forecasts in connection with flight-planning exercises for the Concorde were prepared every day at Heathrow for routes London–New York and London–Anchorage (Alaska). These forecasts covered heights up to 60 000 feet and included specially detailed information for the transonic phase of the flight.

Efforts to persuade weather-sensitive industries of the benefits of seeking meteorological advice were reflected, for example, by an increase of 13 per cent in the number of inquiries from the building and construction industries; the total number of inquiries from this source rose to over 100 000—more than two and a half times the number in 1964. A special climatological service to assist contractors at the tendering and planning stages has been introduced. This provides an assessment of the average frequency of inclement weather in the locality of the operation during the period of construction. Information is given within 24 hours of receipt of a request.

Turning now to our research activities, the topic selected for special mention this year is concerned with the modelling of geophysical motions in the laboratory. Because the motions occurring naturally in the atmosphere and the oceans are so complicated, and cover such a wide range of strongly interacting scales, it is difficult to trace a logical sequence of cause and effect. It is fortunate, therefore, that some of the *basic* motions and mechanisms can be reproduced in relatively simple laboratory experiments and the Office has recently established a new laboratory for this type of work. The results from carefully controlled experiments, in which conditions can be varied at will, have been successfully combined with theoretical studies to improve our understanding of a number of fundamental fluid motions that find application not only in the atmosphere and the ocean but also in the liquid core of the earth and in the atmospheres of some planets.

Project Scillonia, whose objective is to study the structure and evolution of frontal cloud systems and the factors that control the duration, intensity and distribution of their rainfall, continues to make good progress. Successful techniques for determining the three-dimensional air motions on scales ranging

from 10 km to 1000 km, using radar, aircraft and drop-sondes, have been developed, and unique information on the dynamical structure of fronts was obtained during the year.

Our excellent radar facilities at the Royal Radar Establishment, Malvern, were further strengthened during the year by the installation of a unique 10-cm Doppler radar in a steerable reflector with a diameter of 25 metres. This is being used to study echoes from meteorological discontinuities in clear air and should be particularly valuable in studying the organization of convective motions before they become visible as clouds.

A world-wide project, involving laboratories in 17 countries, was carried out in January and February 1969 to investigate spatial and temporal variations in the concentrations of ice nuclei using a technique developed in our laboratories.

Experiments to measure the density of ozone in the high atmosphere were successfully carried out on two BLACK BRANT rockets launched from Fort Churchill, Canada, and two further SKYLARK rockets were launched from Woomera to measure the distribution of molecular oxygen at high levels. The firing of 13 SKUA rockets from Gan revealed that layers of westerly winds alternate with layers of easterlies near the equator, with westerlies prevailing above 50 km.

Considerable effort has been devoted to the development of instrumental techniques for measuring the structure of turbulence in the lowest kilometre of the atmosphere, both over land and sea. Turbulent fluctuations of wind and temperature are measured at various heights from a balloon cable and from a tall tower at Cardington, and plans have been made to use these techniques in a joint investigation with the Air Force Cambridge Research Laboratories at a particularly favoured site in Kansas over the next few years.

The sophisticated 10-level mathematical model which has been developed for the quantitative forecasting of rainfall over the British Isles and western Europe has been further refined and improved. It is now being adapted to cover most of the northern hemisphere on a coarser grid, with a view to using it to predict the evolution of major weather systems for periods of up to a week ahead with the help of the new computer. Experimental forecasts for seven days ahead have been made at the beginning and middle of each month, based partly on numerical predictions for three days ahead and partly on the weather which followed on previous occasions when developments in the middle atmosphere resembled those of the preceding five days. These forecasts have achieved an encouraging degree of success and lend confidence to the belief that the locations of large weather systems are predictable on this time-scale.

Satellites are expected to play an increasing part in meteorological observation for World Weather Watch purposes, and thought has been given to how the United Kingdom might best take a share in this development. As part of the national space programme, a British experimental meteorological satellite has been the subject of a feasibility study and is now in the project-definition phase. Other contributions to World Weather Watch include plans for the establishment of a joint Anglo-French upper air station in the New Hebrides Condominium and for two other upper air stations in the Gilbert and Ellice Islands. Assistance to the World Meteorological Organization (WMO) and developing countries is also continuing on an increasing scale.

The Office has been closely associated in developments which are taking place in oceanography. Meteorologists and oceanographers have a long tradition of co-operative effort since for many important problems it is necessary to regard the atmosphere and the ocean as forming a single system which receives energy from the sun and stores a proportion in the oceans. Plans for a world-wide network of ocean observing stations, providing data for meteorologists and oceanographers, are being developed by a committee set up jointly by WMO and by UNESCO's Intergovernmental Oceanographic Commission (IOC). My Director of Services, Mr P. J. Meade, is co-Chairman of this important committee.

Much effort has been devoted to the design of a building at Bracknell to house the new computer, the telecommunications centre and the Central Forecasting Office. Work on this, and on a new building for experimental physics at Easthampstead, near Bracknell, should start early in the new year.

This has been another good year for recruitment. The Scientific Officer class is up to complement and almost all new entrants this year had either first-class honours or higher degrees. The Experimental Officer class is also fully complemented. Recruitment to the Scientific Assistant class has more than counterbalanced wastage of all sorts to make the long-standing shortage in this class much smaller than it has been for a number of years.

During September, my wife and I made an official visit to the Soviet Union as guests of the State Hydrometeorological Service. In an extensive tour, which took us to Moscow, Leningrad, the Caucasus, Novosibirsk in Siberia, and Tashkent and Samarkand in middle Asia, we saw a broad cross-section of the research and operational activities, including the weather-satellite and large computer facilities, and enjoyed overwhelming hospitality.

Finally, I wish to express deep gratitude to the Lord Hurcomb, who retired in 1969 after twelve years as Chairman of the Meteorological Committee. His interest, enthusiasm and wise counsel will be greatly missed.

B. J. MASON

February 1970
Meteorological Office
Bracknell, Berks.

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FUNCTIONS OF THE METEOROLOGICAL OFFICE

The Meteorological Office is the State Meteorological Service. It forms part of the Air Force Department of the Ministry of Defence. The Director-General is responsible to the Secretary of State for Defence through the Parliamentary Under-Secretary of State for Defence for the Royal Air Force.

The general functions of the Meteorological Office are:

(i) Provision of meteorological services for the Army, Royal Air Force, Civil Aviation, the Merchant Navy and Fishing Fleets.

(ii) Liaison with the Directorate of the Meteorology and Oceanographic Services of the Navy Department and provision of basic meteorological information for use by that Service.

(iii) Meteorological services to other government departments, public corporations, local authorities, the Press, industry and the general public.

(iv) Organization of meteorological observations, including radiation and atmospheric electricity, in Great Britain and Northern Ireland, and at certain stations overseas.

(v) Collection, distribution and publication of meteorological information from all parts of the world.

(vi) Maintenance of certain British observatories.

(vii) Research in meteorology and geophysics.

The Meteorological Office also takes a leading part in international co-operation in meteorology. The Director-General is the Permanent Representative of the United Kingdom with the World Meteorological Organization.

Except for the common services provided by other government departments as part of their normal function (e.g. accommodation by the Ministry of Public Building and Works, and stationery by Her Majesty's Stationery Office) the cost of the Meteorological Office is borne by Defence Votes.

The gross annual expenditure on the Meteorological Office, including that on the common services, is approximately £9·6 million. Of the amount chargeable to Defence (Air) Votes, about £6·3 million represents expenditure associated with staff and £3·0 million expenditure on stores, communications and miscellaneous services. Some £2·0 million is recovered from other government departments and outside bodies in respect of special services rendered, sales of meteorological equipment, etc.

METEOROLOGICAL COMMITTEE

Terms of reference:

(*a*) To keep under review the progress and efficiency of the Meteorological Service and the broad lines of its current and future policy.

(*b*) To keep under review the general scale of effort and expenditure devoted to the meteorological services.

(*c*) To ensure the maintenance of adequate contacts between the Meteorological Service and those who use its services.

Membership at 31 December 1969:

Chairman:

Members: Mr A. F. Hetherington, D.S.C.
The Rt Hon. Lord Mais, O.B.E., T.D.
Professor J. P. Hudson, M.B.E., G.M.
Professor R. C. Sutcliffe, C.B., O.B.E., F.R.S. (Chairman, Meteorological Research Committee) (*ex officio*)

Secretary: Mr D. Hanson (Secretary, Meteorological Office)

The Committee met once in 1969. The chairmanship, vacant following the retirement of the Lord Hurcomb, G.C.B., K.B.E., in 1969, has now been filled by the appointment of the Earl of Halsbury, F.R.S.

ADVISORY COMMITTEE ON METEOROLOGY FOR SCOTLAND

Terms of reference:

(*a*) To review the development of meteorological science and its application to Scotland.

(*b*) To submit to the Meteorological Committee any proposals in connection therewith.

Membership at 31 December 1969:

Chairman: Dr B. J. Mason, F.R.S. (Director-General, Meteorological Office)

Members: Professor J. N. Black, F.R.S.E. (University of Edinburgh)
Dr S. C. Curran, F.R.S. (Royal Society)
Mr W. O. Kinghorn (Department of Agriculture and Fisheries for Scotland)
Mr J. Paton, F.R.S.E. (Royal Society of Edinburgh)
Professor P. A. Sheppard, C.B.E., F.R.S. (Royal Meteorological Society)
Mr J. W. Shiell (Scottish Development Department)
Dr J. Steele (Department of Agriculture and Fisheries for Scotland)
Dr R. W. H. Stevenson (University of Aberdeen)
Professor D. W. N. Stibbs, F.R.S.E. (University of St Andrews)
Professor P. A. Sweet (University of Glasgow)

Secretary: Mr R. Cranna (Meteorological Office)

The Committee met once in 1969.

METEOROLOGICAL RESEARCH COMMITTEE

Terms of reference:

The Meteorological Research Committee will advise the Parliamentary Under-Secretary of State for Defence for the Royal Air Force on the general lines along which meteorological and geophysical research should be developed within the Meteorological Office and encouraged externally. It shall review progress and report annually.

It is empowered to appoint sub-committees, one of which shall be responsible for advising on the usage of monies allocated annually from Air Votes for research projects conducted outside the Meteorological Office. The Committee will be responsible for co-ordinating the work of its subcommittees.

Membership at 31 December 1969:

Chairman: Professor R. C. Sutcliffe, C.B., O.B.E., F.R.S.

Members: Instructor Captain J. D. Booth, R.N. (Director, Meteorology and Oceanographic Services (Naval))
Professor R. L. F. Boyd, F.R.S.
Wing Commander E. W. Bunkhall
Professor H. Charnock
Professor D. R. Davies
Dr G. E. R. Deacon, C.B.E., F.R.S.
Dr R. Frith, O.B.E. (Deputy Director, Physical Research, Meteorological Office)
Dr E. R. R. Holmberg (Army Department)
Dr J. T. Houghton
Mr E. Knighting (Deputy Director, Dynamical Research, Meteorological Office)
Professor M. J. Lighthill, F.R.S.
Dr B. J. Mason, F.R.S. (Director-General, Meteorological Office)
Mr P. J. Meade, O.B.E. (Director of Services, Meteorological Office)
Mr D. E. Morris (Ministry of Technology)
Mr J. Paton, F.R.S.E.
Mr J. S. Sawyer, F.R.S. (Director of Research, Meteorological Office)
Professor P. A. Sheppard, C.B.E., F.R.S.

Secretary: Mr F. E. Dinsdale (Meteorological Office)

The Committee met twice in 1969 and its subcommittees seven times.

PRINCIPAL OFFICERS OF THE METEOROLOGICAL OFFICE

DIRECTOR-GENERAL

B. J. Mason, D.Sc., F.R.S.

DEPUTY TO THE DIRECTOR-GENERAL

P. J. Meade, O.B.E., B.Sc., A.R.C.S.

DIRECTORATE OF RESEARCH

DIRECTOR	J. S. Sawyer, M.A., F.R.S.

PHYSICAL RESEARCH

DEPUTY DIRECTOR	R. Frith, O.B.E., Ph.D.
SPECIAL POST	F. Pasquill, D.Sc.
GEOPHYSICAL FLUID DYNAMICS LABORATORY	R. Hide, D.Sc.
METEOROLOGICAL RESEARCH FLIGHT	C. J. M. Aanensen, M.Sc.
OBSERVATORIES AND MICROMETEOROLOGY	
Assistant Director	L. Jacobs, M.A., M.Sc.
CLOUD PHYSICS	
Assistant Director	P. Goldsmith, M.A.
HIGH ATMOSPHERE	
Assistant Director	R. A. Hamilton, O.B.E., M.A., F.R.S.E.
Special Post	K. H. Stewart, Ph.D.

DYNAMICAL RESEARCH

DEPUTY DIRECTOR	E. Knighting, B.Sc.
SPECIAL INVESTIGATIONS	
Assistant Director	R. F. Jones, B.A.
FORECASTING RESEARCH	
Assistant Director	F. H. Bushby, B.Sc., A.R.C.S.
SYNOPTIC CLIMATOLOGY	
Assistant Director	R. A. S. Ratcliffe, M.A.
Special Post	J. M. Craddock, M.A.
Special Post	H. H. Lamb, M.A.
PUBLICATIONS AND TRAINING	
Assistant Director	K. H. Smith, B.Sc.
DYNAMICAL CLIMATOLOGY	
Assistant Director	G. A. Corby, B.Sc.
Special Post	R. J. Murgatroyd, O.B.E., Ph.D., C.Eng., M.I.E.E.

DIRECTORATE OF SERVICES

DIRECTOR	P. J. Meade, O.B.E., B.Sc., A.R.C.S.
INTERNATIONAL AND PLANNING	
Assistant Director	D. G. Harley, B.Sc.

FORECASTING SERVICES

DEPUTY DIRECTOR	V. R. Coles, M.Sc.
CENTRAL FORECASTING	
Assistant Director	R. F. Zobel, O.B.E., B.Sc.
Chief Forecasting Adviser	T. H. Kirk, B.Sc.
TELECOMMUNICATIONS	
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DEFENCE SERVICES	
Assistant Director	T. N. S. Harrower, M.A., B.Sc.
H.Q., Strike Command	E. Evans, M.Sc.
PUBLIC SERVICES	
Assistant Director	J. K. Bannon, B.A.
London/Heathrow Airport	M. H. Freeman, O.B.E., M.Sc.

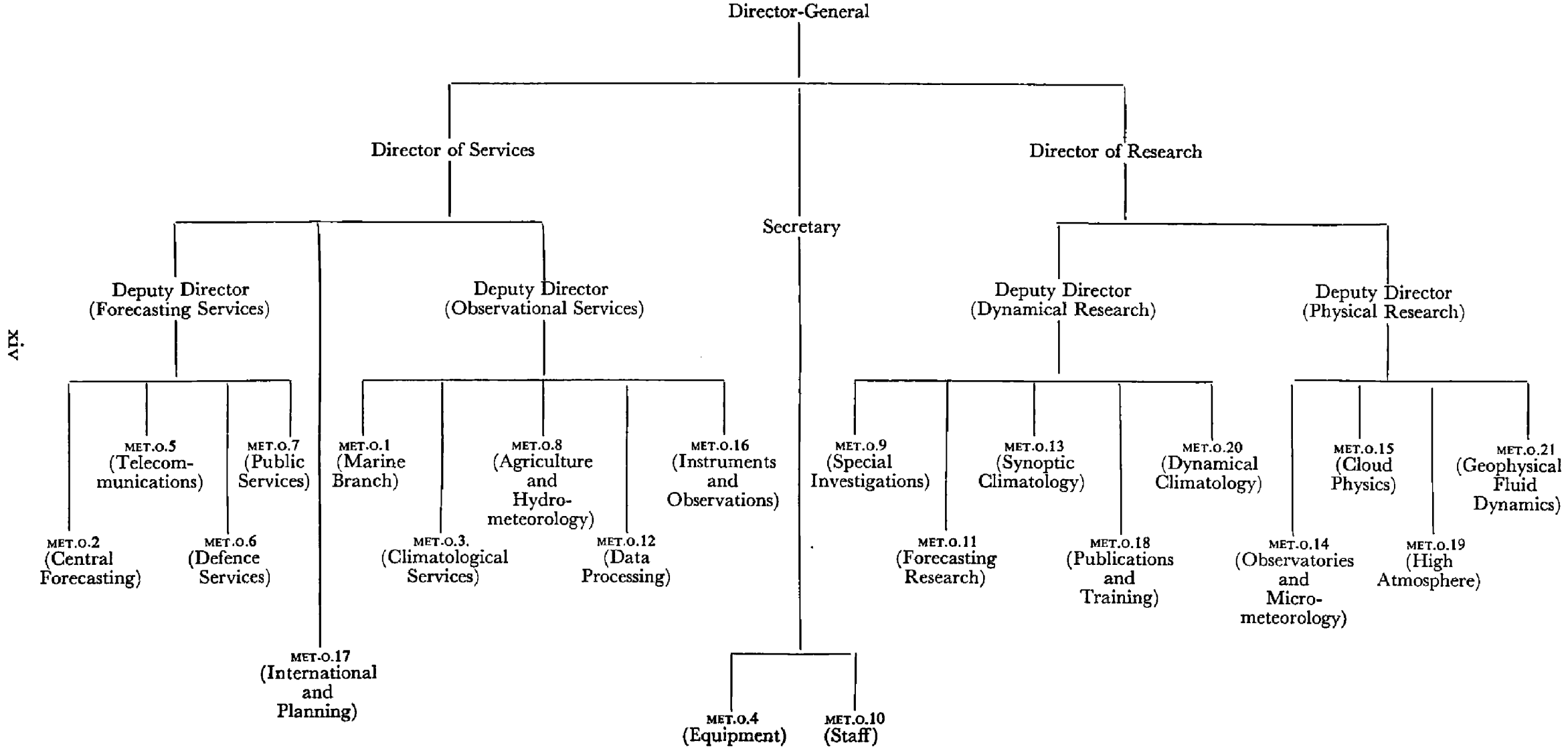
OBSERVATIONAL SERVICES

DEPUTY DIRECTOR	R. H. Clements, M.A.
MARINE BRANCH	
Marine Superintendent	G. A. White, Captain, **Extra** Master
CLIMATOLOGICAL SERVICES	
Assistant Director	J. H. Brazell, M.Sc.
AGRICULTURE AND HYDROMETEOROLOGY	
Assistant Director	J. Harding, B.A., M.Sc.
Special Post	L. P. Smith, B.A.
DATA PROCESSING	
Assistant Director	N. Bradbury, B.Sc.
INSTRUMENTS AND OBSERVATIONS	
Assistant Director	N. E. Rider, D.Sc.

SECRETARY, METEOROLOGICAL OFFICE D. Hanson, M.A.

METEOROLOGICAL OFFICE HEADQUARTERS ORGANIZATION

(at 31 December 1969)



THE DIRECTORATE OF SERVICES

Special Topic—Meteorological Telecommunications

In order to prepare weather forecasts meteorologists must be able to receive, at regular intervals throughout the day and with the least possible delay, meteorological observations from a large number of stations distributed over the hemisphere or even over the whole globe. To satisfy this major requirement there must be a high degree of co-operation among meteorological services in all countries and observations of all kinds must be collected and disseminated by means of an efficient world-wide telecommunications system.

With the development of the electric telegraph in the 1840s meteorologists realized that the means were becoming available for the rapid exchange of weather reports. Accordingly arrangements were made for an international meteorological conference and this, the forerunner of many that have taken place since, was held in 1853.

Since those days of the mid-19th century meteorological telecommunications have been established and have grown throughout the world, establishment and growth being due to both international collaboration and national effort. They have been founded on a requirement to support meteorological services. This requirement is both national and international. Its fulfilment is not only dependent on national planning but also on international organization and co-operation.

Today, international organization in meteorological matters falls within the purview of the World Meteorological Organization (WMO) of which, with few exceptions, all countries of the world are Members. It is through the sponsorship of WMO that international networks of meteorological observations have been created and it is through the agency of WMO that observational information is collected and distributed on an international basis. It is also through agreement within WMO that international meteorological services are provided.

The associated international meteorological telecommunications are technically planned within WMO. Planning is largely carried out by working groups of specialists in telecommunications. There are seven such working groups. The WMO Technical Commission on Synoptic Meteorology establishes one to deal with world-wide telecommunications matters and each Regional Association of WMO, of which there are six (Africa, Asia, South America, North and Central America, South-west Pacific, Europe), establishes one to deal with regional telecommunications matters. WMO, however, is not equipped with funds for the financing of meteorological telecommunications; such financing is a matter for the Member countries directly concerned.

Observational information is derived by observation of the actual state of the atmosphere and of the earth's surface in terms of the meteorological elements and in relation to a space/time observational network. It is upon this information that the meteorologist bases his analyses and forecasts of meteorological situations. The observational information is usually regarded as basic and the analyses and forecasts are often referred to as processed information.

Requirements for exchanges of meteorological data vary according to the area of interest or responsibility and depend on whether analyses and

forecasts have to be prepared for the whole area of the globe, for a region or continent, or for a single country. For global studies the so-called global observational network consists of some 4000 stations where surface observations are made at regular intervals throughout the 24 hours and of some 700 stations where measurements of wind, pressure, temperature and humidity in the upper air are made twice a day by means of balloon-borne radiosonde and radar wind ascents. For regional and national purposes a denser network of surface observing stations is required and the observations are made more frequently, at least every three hours in general but at hourly or half-hourly intervals at observing stations that are situated on airfields.

The collection and dissemination of observational information is therefore a very complicated requirement for a meteorological telecommunications system to meet. Not only has the system to accept messages for transmission largely at the same times at all centres in the system but dissemination patterns vary from centre to centre according to each centre's national, regional and global responsibilities. Furthermore observational information should reach meteorologists with the least possible delay and this means a very tight transmission schedule. For example, in scheduling transmissions on a global basis the target time for completion of collection and dissemination of synoptic observational information is two hours from the standard time of observation.

Normally, in a country there is a National Meteorological Centre (NMC) which is the focal point of the country's meteorological services. These services are provided for the country's various user interests such as the general public, aviation, shipping, agriculture and public utilities. They are provided either direct or through meteorological offices distributed throughout the country usually to serve specific requirements. Though services are centralized on the NMC, a meteorological office in the country has a measure of autonomy for carrying out specific responsibilities for the user interest it serves. Internationally there is a complementary overlay of centralized services. These international services are provided by World Meteorological Centres (WMC) and Regional Meteorological Centres (RMC). The WMCs are at Washington, Moscow and Melbourne. Their functions are to process meteorological information on a global scale sufficient to meet needs throughout the world. The RMCs are required to process meteorological information on a scale sufficient to meet needs within their respective regions.

As with observational information, processed information is mostly presented for transmission over the telecommunications system on a 24-hour periodic basis and presentation is around the same times at all telecommunications centres associated with WMCs and RMCs. Completion of distribution has to be in reasonable time for the processed information to be effective in the provision of meteorological services. For example, the target time for completion of distribution, on a global basis, of WMC products is four hours from the standard time of observation on which the products are based. Subtracting two hours for collection and transmission of observational information (global) to the WMCs and allowing for processing, there is not very much time left for the distribution of the information processed by the WMC.

Altogether it is evident that meteorological telecommunications have to meet very exacting meteorological operational requirements, not only in the collection and dissemination of observational information but also in the

distribution of processed information. It is important to note however that these requirements are derived solely in the context of providing meaningful meteorological services. It is the responsibility of the telecommunications to meet the requirements to the utmost practical extent, on the principle that the time spent by meteorological information within a telecommunications system is time lost in the provision of meteorological service.

Meteorological services are dependent upon the availability and nature of the support provided by the meteorological telecommunications at any one time, but all the time the demands upon telecommunications for much greater speeds of transmission, with no corresponding decline in reliability and serviceability, are becoming ever more exacting. Today, the potential effectiveness of meteorological services has been increased enormously with the introduction of computer-based numerical techniques in meteorology and with the utilization of automated plotting and line-drawing facilities. Centralization, in consequence, is now more than ever a feature of international and national meteorological services and it is clear that telecommunications have a particularly vital role if the full benefits of centralization are to be realized.

The increased accent on centralization in the provision of meteorological services is understandable when account is taken of the cost of computers and of automated facilities and of the fact that so much can now be done objectively in the processing of meteorological information which could not have been attempted by the subjective methods of years ago. Also, with objective methods there is less call than with subjective methods for different meteorological offices to do the same processing. Centralization, however, has no meaning if centralized processing cannot be carried out at the right time and in the right time-scale and if the products of centralized processing cannot be communicated to the user in time to meet requirements. Furthermore, centralized services have only a restricted application if they are based solely on meeting common-user requirements. They are more effective if they also cater, where it is advantageous to do so, for particular needs. A balance, however, has to be struck in meeting requirements—a balance between the services to be provided centrally on a common-requirement basis but with reasonable scope for the major individual needs and those services to be provided locally within the framework of the centralized services. All this means that the meteorological telecommunications should be designed to:

(i) support centralized services,

(ii) support local meteorological services, and

(iii) provide two-way links between centralized services and local services.

A most important aspect of international collaboration is World Weather Watch (WWW). This is based on a concept of advancing the science and practice of meteorology to the benefit of all by seizing and using the opportunities offered by modern scientific and technical developments. WWW is a recognition that with utilization of modern computer technology the meteorologist is in a position, at long last, to treat the atmosphere globally.

Among the elements of WWW are:

(i) The Global Observation System which embraces world observational networks and other observational facilities such as those provided by satellites.

(ii) The Global Processing System which covers arrangements for the processing of meteorological observational information at World Meteorological Centres and Regional Meteorological Centres.

(iii) The Global Telecommunications System (GTS), the purpose of which is to cater for the collection and distribution of observational information to WMCs, RMCs and NMCs, to exchange processed information between WMCs and RMCs and distribute processed information to NMCs.

In all three elements there should be consistency in effort and in utilization of modern techniques. Co-ordination in advancing the three elements is vital. If anything, the GTS should be continuously engineered so that it is always ahead of the other two; this calls more than ever before, for system planning of meteorological telecommunications both internationally and nationally.

System planning of meteorological telecommunications implies evaluation of different systems and determination of the best in terms of cost effectiveness—cost relating not only to finance but also to utilization of available manpower and of facilities. It requires determination of the:

(i) characteristics of the traffic to be carried by the system,
(ii) utilization of the system,
(iii) acceptable levels of integrity and reliability of the system,
(iv) acceptable levels of serviceability of the system,
(v) interface of the system with:
  (*a*) existing meteorological telecommunications systems,
  (*b*) telecommunications systems other than meteorological,
(vi) interface with meteorological computers utilized in the processing of meteorological information,
(vii) interface with automated facilities such as automatic plotters and line-drawers,
(viii) capacity for expansion and evolution, and
(ix) obsolescence factor.

System planning is a continuing process and WMO is already actively engaged in planning the evolution of the GTS. The Members of WMO have agreed that the GTS shall be based on a Main Trunk Circuit girdling the earth and linking the telecommunications centres of the WMCs Melbourne, Moscow and Washington. They have designated Regional Telecommunications Hubs (RTHs) with regional responsibilities for the collection, storage and distribution of meteorological information compatible with the flow of traffic over the Main Trunk Circuit. Furthermore they have stipulated the engineering and operating characteristics of the Main Trunk Circuit and of the telecommunications centres at the WMCs and the RTHs.

The planning has been taken a stage further on a regional basis by the development of complementary network configurations in respect of regional telecommunications. Figure 1 shows the Main Trunk Circuit and the planned network configuration for the European Region. The aim of WMO is implementation of the Main Trunk Circuit and the European network by January 1971.

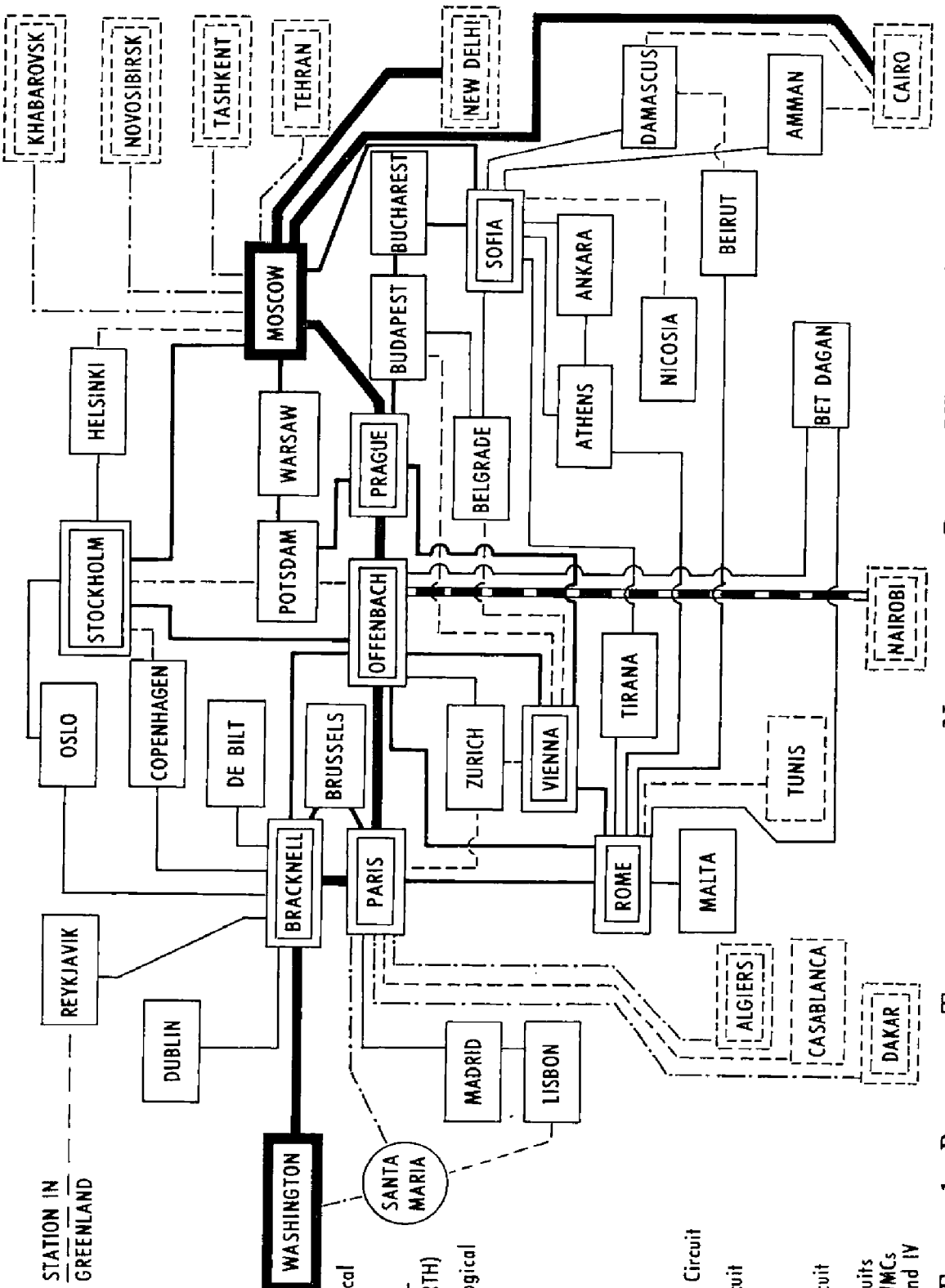


FIGURE 1—REGIONAL TELECOMMUNICATIONS NETWORK FOR REGION VI (EUROPE)

Now turning from the general to the particular, the National Meteorological Centre of the United Kingdom is at the Headquarters of the Meteorological Office, Bracknell. So also is the United Kingdom Meteorological Telecommunications Centre (Met.T.C.). WMO has designated Bracknell as a Regional Meteorological Centre. It has also designated Met.T.C., Bracknell, as a Regional Telecommunications Hub on the Main Trunk Circuit of the GTS. The centralized meteorological services provided by the NMC/RMC Bracknell are computer-orientated. What then of the system planning and development of the meteorological telecommunications of the United Kingdom, especially of Met.T.C., Bracknell?

In 1968, a System Design Study of U.K. meteorological telecommunications was carried out in regard to national and international responsibilities. It was a three-month study undertaken by expert teams from the telecommunications industry. Its purpose was to look at the existing meteorological telecommunications and arrive at conclusions as to how best to modernize in order to meet:

(i) meteorological operational requirements,
(ii) meteorological telecommunications operational requirements, and
(iii) meteorological telecommunications technical requirements.

The basic objective of the study was the production of a system plan for modernization. The system plan was to be designed in such a way that implementation would not only incorporate the best and most suitable of present known techniques but would also ensure that the implemented modernized system would be capable of absorbing new techniques as they became available for practical application. It was, however, to be contained within the practical technical environment and not involve research and development. The plan was to be supported with information on cost effectiveness. It was also to cover any need for phasing-in of the planned new system whilst the existing system, in whole or in part, was retained in operational service.

Within the framework of the basic objective, the study was to cover such matters as:

(i) automation of Met.T.C., Bracknell,
(ii) optimum utilization of medium–and high-speed operation in the transmission of meteorological information, and
(iii) provision of request/reply facilities for meteorological offices as well as routine transmissions.

The study was well worth while and set the stage for development and evolution of U.K. meteorological telecommunications. One of the major problems for further study arose from the fact that some meteorological information such as synoptic observation information is in alpha-numeric format (i.e. made up of groups using letters of the alphabet and numbers) whilst other information, such as satellite pictures and charts of processed information, is in pictorial format. The meteorologist uses the information in both these formats and it is a meteorological requirement that the information be presented to him in the required format, either as page copy or on display. Transmission of pictorial information is currently based on an analogue facsimile mode of operation and this is now far too slow. The problem is how to speed up the transmission of information in pictorial format. The solution lies in utilization of a digital mode of transmission rather than an analogue mode.

The outcome of the study was that the United Kingdom meteorological telecommunications system is to be developed in terms of the following phases:

Phase I
Automation of Met.T.C., Bracknell, so that it is ready to be a Regional Telecommunications Hub on the Main Trunk Circuit Washington–Moscow in 1970.

Phase II
Automation of Met.T.C., Bracknell, in respect of all data telegraph land-line transactions by early 1971.

Phase III
Movement in 1971/72 of Met.T.C., Bracknell, to new accommodation at Bracknell and provision of interface (using a high-speed data link) with a new meteorological computer.

Phase IV
Up-dating of the whole national meteorological telecommunications system in the five-year period following automation of Met.T.C., Bracknell.

Contracts were placed early in 1969 with the Marconi Company Ltd in respect of Phases I and II. Automation is to be based on a dual computer configuration with a true no-break power supply. Four computers are to be provided to cover transition from Phase I to Phase II and from Phase II to Phase III.

The automated complex in respect of data transmission is to be capable of:

(i) Speed conversion from low to medium or high speeds, from medium to high speeds and vice versa. *Note:* A transmission speed of 2400 bits/s is to be used on the Main Trunk Circuit. A transmission speed of 1200 bits/s is to be used on some regional circuits terminating at Bracknell (1 bit = 1 binary digit).

(ii) Alphabet conversion.

(iii) Error detection and correction in the case of transmissions at medium and high speeds.

(iv) Automating to an optimum extent message routeing, message editing, message preparation and message storage. Storage is to be sufficient for 24-hour retention.

The automated complex is also to provide for a limited amount of quality control of the meteorological content of synoptic observational information. As regards analogue facsimile transmissions, arrangements are to be provided for switching from data transmission to analogue facsimile transmission and vice versa. However, until such time as analogue facsimile mode of operation can be replaced by a digital facsimile mode there will continue to be a measure of manual operation required in facsimile transmissions.

The automated complex will in essence be a real-time switching centre and from the standpoint of international telecommunications it will be a part of an international automated complex comprising many such centres. Inherent programming, as distinct from executive programming, of a real-time switching system cannot be changed without taking the system out of service. Such closures, particularly as regards centres on the Main Trunk Circuit, are unlikely to be acceptable. It would seem then that the only recourse

is to make sure that, in the initial inherent programming of a real-time switching system, changes which may be required later are anticipated. It is also important in an automated international complex that one automated centre can converse (electronically) with another such centre at the end of a linking telecommunications channel. To ensure this, international operational procedures must be precisely defined so that they can be translated into programming and there must be an agreed time at which the procedures are frozen. Putting it another way, the establishment of an automated centre in an international automated complex must be on an interdependent basis and not on an independent basis.

Meetings have been held at frequent intervals with those telecommunications centres which are to be linked to Bracknell in the international automated system so as to ensure that the Bracknell automated complex is compatible with those at other centres. The next step is to introduce operational trials whilst maintaining the existing largely manually operated telecommunications. This step is to be taken in 1970.

The Bracknell automated complex is undoubtedly one of the first, if not the first, real-time automated switching system in the United Kingdom which is to cater for medium- and high-speed data transmission, with error detection and correction, and operate continuously for 24 hours of the day, every day of the year. It presents a challenge to telecommunications engineering, to programming, to maintenance and to operating staff. Although much of the old radio facilities and services will be continued at Bracknell, particularly those services to the ocean weather stations in the North Atlantic and the radio-facsimile and teleprinter broadcasts, operating staff at Met.T.C., Bracknell, will progressively move towards utilization of automated facilities. Training is to be provided to this end.

The future holds tremendous possibilities for meteorological telecommunications in the United Kingdom. It should be appreciated that planning and development of Met.T.C., Bracknell is not an end in itself but an essential part of the overall planning of the U.K. system—a system which has to be closely integrated to meet both national and international requirements.

In conclusion it should be mentioned that the responsibility for the planning and provision of telecommunications to meet the requirements of the Meteorological Office rests primarily with the Director-General of Signals of the Air Force Department of the Ministry of Defence. The great indebtedness of the Office to that Directorate is gratefully acknowledged. The Office is also indebted to the Directorates of Electronics Research and Development and of Electronics Production of the Ministry of Technology for their considerable effort on behalf of meteorological telecommunications.

General

Activity continued at a high intensity throughout the year. The demands of aviation, agriculture, industry and commerce generally, and of the public have been increasing steadily year by year and 1969 was no exception. Some decisive stages were reached among support services with substantial progress in the modernization of the telecommunications system, the placing of an order for a new computer of adequate power, further stages towards the operational use of the new radiosonde, and the granting of funds to purchase 10 automatic weather stations for operational trials and further development.

On the organization side preparations were completed, for implementation on 1 January 1970, for the formation of a new branch with responsibilities over the whole range of data requirements and observational techniques, standards and procedures. The process was largely one of integration since in the past these responsibilities had been divided among several branches. The new branch is therefore designed to fill an essential role between instrument development and production on the one hand and on the other hand the forecasting and applied climatology branches which are using meteorological data to meet requirements for services. The nautical organization, headed by the Marine Superintendent, will form a part of this new branch, a most convenient arrangement in view of the major need to develop world-wide ocean-observing networks.

Hydrology, or hydrometeorology where the Office's special interests lie, has given rise to a great deal of important work, much of it fairly long term. The Chester Dee experiment using radar as well as conventional rain-gauges to provide an operational rainfall service to aid in the control of regulating reservoirs, a comprehensive study of the floods that have occurred in the United Kingdom, and a complementary study of droughts are all examples of applied research of the greatest economic importance.

Forecasting Services

Central Forecasting Office

The Central Forecasting Office (CFO) has three primary forecasting objectives. The first of these is the provision of guidance for outstations, mainly by means of charts depicting actual and forecast synoptic conditions, augmented by advisory texts covering the next 2–3 days.

Secondly, CFO is responsible for routine forecasts for sea and land areas and for the notification of expected specified weather such as fine spells or of warnings of hazardous conditions. The forecasts are mainly intended for dissemination by the Press, broadcasting and television, but some are issued direct to public utilities such as the Central Electricity Generating Board and to industry. The hazardous conditions for which warnings are issued include gales for land and sea areas, fog, snow, icy roads, thunderstorms, frost, thaw and strong upper winds.

Thirdly, CFO is a Regional Meteorological Centre within the concept of World Weather Watch (WWW). In this role CFO undertakes to meet the needs

of various countries in Europe for certain regional forecasts. It fulfils this role by the preparation, for wireless-telegraphy and radio-facsimile transmission, of actual and forecast charts covering a large area of the North Atlantic Ocean, Europe and the Arctic.

Forecasts of wave height and direction are produced as routine by computer for the North Atlantic area, for periods up to 48 hours ahead. These are broadcast as a WWW requirement for the benefit of other European maritime nations and of ships at sea. They are also required by CFO in connection with its ship-routeing service.

During 1969, 195 ships have been routed across the Atlantic in one direction or the other. This compares with 104 ships routed in nine and a half months of 1968, the service having been inaugurated in mid-March of that year. It is gratifying that this service is gradually becoming more widely used. The object is to provide the ships with advisory routes or courses to steer, so that the time of crossing will be the least, commensurate with the avoidance of wave conditions liable to cause damage to the ship or its cargo. The method used remains that adopted for the ship-routeing experiment carried out in 1967. The speed of the vessel along various possible tracks is estimated in relation to the predicted wave fields, having regard also to conditions expected in the outlook period beyond 48 hours ahead. However, before offering advice to the master of a vessel it is necessary to consider also a number of other factors, such as fog, icebergs, ocean currents and any special conditions which may be important to a particular vessel on a particular voyage.

Advisory forecasts were supplied to the meteorologist on board the fishery advisory vessel *Orsino* in northern Iceland waters until the end of April. This service was revived in December.

Cloud photographs from the automatic picture transmission (APT) of the United States ESSA weather satellites have continued to be received at Bracknell daily and are a routine aid in the preparation of analyses over the North Atlantic and European areas. Interpretations of the pictures (nephanalyses) have been prepared for issue to outstations by land-line facsimile and radio-facsimile. These nephanalyses are made from pictures received during the two orbits nearest to the British Isles. They are of considerable value to the outstations in their day-to-day work and in the briefing of aircrews.

The plotting and analysis of ice conditions in the northern hemisphere has continued and regular broadcasts are made to assist navigation in waters subject to sea ice, as well as to assist other meteorological services. During the polar summer the APT pictures mentioned above are of considerable value in delineating the edges of the main icefields, though the resolution is insufficient to depict individual icebergs. The operational APT satellites do not at present produce infra-red photographs, so that in winter only the time-honoured reconnaissance methods can be employed. However, an example of an infra-red photograph from an experimental satellite is shown as Plate VIII. The ice charts also show sea temperature isotherms, and separate charts of isotherms are issued on a daily basis for coastal waters of the British Isles. The temperature data for these purposes are all processed by computer.

The computer-programming unit of CFO has introduced a number of modifications into the operational numerical forecasting procedures during the year. These have resulted in improved analyses on which to base the forecasts, which in turn are themselves improved. Improvements have also been made in

forecasts useful to aviation, especially of temperatures at normal flight levels. The assistance given to certain major outstations, notably London/Heathrow Airport, Headquarters Strike Command and Headquarters Air Support Command of the Royal Air Force has therefore been enhanced. Assistance is also given directly to the British Overseas Airways Corporation by the provision of forecast parameters required for flight-planning purposes.

The programming unit has also developed a mathematical method, based on the use of orthogonal polynomials, for three-dimensional analysis and it has begun work on a four-dimensional analysis. These techniques will be important for the future operational development of forecasting models now in the research stage and for incorporating data at non-standard times and levels such as observations of wind from aircraft, or of temperature from orbiting satellites.

CFO remains responsible for the publication of the *Daily Weather Report* (DWR) with its *Overseas Supplement* and *Monthly Summary* and the *Daily Aerological Record* (DAR). Copy for these publications is largely extracted by computer methods.

Services for the general public

Forecasting services for the public—including agriculture, industry, commerce and the public utilities—are provided directly by the weather centres and a number of other forecasting offices, or indirectly through the mass communications media. These media include the radio and television services of the British Broadcasting Corporation, the companies of the Independent Television Authority, the national and provincial Press, the GPO's automatic telephone weather service (ATWS) and the GPO's coastal broadcasting stations.

The public demand for weather information for a wide variety of purposes continued to grow and, during 1969, direct calls received at the various weather centres and forecasting offices reached a new record total of 1 610 484 compared with 1 480 262 in 1968, i.e. a growth rate over the 12-month period of 8·8 per cent compared with an average growth rate of 11 per cent over the previous six years.

The February snowfalls resulted in an unprecedented demand for meteorological information. Weather Centres and other forecasting offices handled 194 000 public inquiries during the month; London Weather Centre alone dealt with 45 000 inquiries, including 3000 in a single day. At times, the pressure on some forecasting offices, particularly those with a relatively small staff, proved almost overwhelming and staffs had the greatest difficulty in coping with the flood of inquiries. In an attempt to alleviate similar situations in the future, arrangements were made for a telephone-answering set to be made available at several offices on a trial basis; in exceptional circumstances when pressure of work is such that the available staff are unable to provide a personal service for all telephone inquiries, the answering set carrying a pre-recorded forecast is switched on to one of the GPO directory lines. The recording is switched out as soon as the pressure of work allows a return to personal service.

Several discussions were held with representatives of the Ministry of Transport and the BBC with a view to widening the dissemination of road danger warnings to the motorist and the public at large. With the full and willing co-operation of the BBC, the broadcasting on BBC Radio 2 of warnings of fog

and strong winds on motorways was extended to include warnings of snow and/or icy roads in all parts of the United Kingdom. In addition, special warnings of snow affecting any part of England, Scotland and Wales are prepared by the Central Forecasting Office for broadcast at 1600 BST each day on BBC Radio 2. Arrangements were also made for FLASH warnings of severe weather likely to be of concern to the motorist to be passed to the BBC Motoring Unit for inclusion in their bulletins broadcast on BBC Radio 2.

The dissemination of routine forecast information via the mass media continued. The specialist broadcasts for farmers on BBC 1 Television and BBC Radio 4 remained unchanged except that, in Scotland, arrangements were made for the inclusion of a medium-range forecast twice weekly in the BBC Radio 4 programme 'Farm Journal'. As in previous years during the summer weekends the 'weathermen' augmented the daily forecasts broadcast by the BBC with forecasts for sea crossings and for the major continental resorts. A similar service covering weekend outlooks for British holiday resorts and sea crossings was provided each Friday on BBC Radio 2.

Local radio stations continued to make full use of routine forecasts; they also showed a ready appreciation of the value of the meteorological services and were quick to grasp opportunities of injecting weather information of local topical interest into their programmes, e.g. throughout the peak summer months Radio Brighton broadcast forecasts specially tailored for the sailing community, while Radio Nottingham relayed reports and forecasts for popular holiday destinations over the late summer Bank Holiday.

In the field of television, the year was, for the greater part, one of uncertainty and change. The 'weathermen' at the BBC Television Centre continued their thrice-daily presentations on BBC 1, but problems arising from changes in programme schedules and the introduction of colour television resulted in a reduction from one minute to 30 seconds in the time allotted for the early evening presentation. The situation with regard to independent television was also not encouraging. A large volume of protest followed a further increase in charges for meteorological services levied on the companies early in the year—an increase made necessary by the rising cost of providing the service—and two companies opted out of the service altogether while others cut back their requirements presumably to keep down costs. In spite of strenuous efforts by the Meteorological Office at least to maintain the *status quo*, the meteorological service to the public through the medium of television undoubtedly suffered a set-back during the year.

Several broadcasts and talks were given by various members of the staff on radio and television; most of these dealt with past and current weather. The Meteorological Office co-operated with the BBC in the production of documentary programmes for radio and television on the west-country storms and floods of July 1968 and of a 30-minute feature programme entitled 'Tomorrow's Weather' for broadcast on the BBC World Service. A BBC television film unit visited the London Weather Centre and produced a short film 'The work of the London Weather Centre'.

The automatic telephone weather service (ATWS) was extended to Coventry, Doncaster and Swindon. The total number of calls made on ATWS during 1969 was 12 401 471 compared with 10 016 877 in 1968, an increase of 24 per cent.

On the industrial front as a whole special efforts continue with the aim of encouraging industrialists to look more carefully at the effects of weather on their activities and at the possible benefits that use of meteorological advice might produce.

The construction industry continues to show the most lively interest in this field. Building and civil engineers made 100 399 requests for advice on weather during 1969, an increase of 13 per cent over 1968 and two and a half times the number in 1964. The special forecasting service for large construction sites remains popular and there is a wide diversity in the nature of contracts for which this service is provided, covering motorway construction, dam building, the erection of a nuclear power station, the laying of a large main for North Sea gas, factory and large office-block construction and housing-estate building. For very many more contracts a service is provided which warns the contractor of the approach of weather that might affect his work programme.

The two research studies sponsored by the Construction Industry Research and Information Association and being conducted by Senior Research Fellows working in the Department of Civil Engineering in the University of Sheffield are under way. These studies concern the effects of wet weather on earth-working and the use of meteorological services in construction. Some suitable sites have been chosen where field studies can be carried out. The Meteorological Office is co-operating in this work by helping in the choice of sites and by providing a weather advisory service.

In January a special climatological service to assist contractors at the tendering and planning stages was introduced. This provides an assessment of the average frequency of inclement weather in the locality of a contract during the period of construction. Information is given within 24 hours of receipt of a request. Some 63 inquiries for this service have been received from 41 firms.

The Horserace Betting Levy Board has approached the Office for advice on weather problems affecting the racing programmes under National Hunt and Jockey Club rules. Weather caused the abandonment of many meetings throughout the country in the 1968–69 season and the Board is considering rearranging meetings in the light of the susceptibilities of individual courses to adverse weather at particular times of the year. Discussions have been held between the Board's representatives and the Meteorological Office on the various factors involved and a study has been carried out of the liability of racecourses to frost.

The changing requirements for meteorological services of the gas and electricity industries were the subject of several meetings with representatives of the Gas Council and the Central Electricity Generating Board. As a result, the service to the gas industry was expanded, and a standardized service to the various Grid Control Centres of the CEGB was introduced.

Arrangements were made in conjunction with the Welsh Office for the issue of special forecasts on the occasion of the Investiture of H.R.H. the Prince of Wales at Caernarvon on 1 July.

Special forecasts were also issued for some of the main sporting events of the year, including the cricket test matches, the lawn tennis championships at Wimbledon, Royal Ascot and the Derby.

The work of the Weather Centres at London, Glasgow, Manchester, Southampton and Newcastle and the public service office at Watnall (near Nottingham) continued to increase, though casual inquiries fluctuated widely

according to the weather conditions. The total numbers of inquiries dealt with by the individual centres over the past three years are shown below:

	London	Glasgow	Manchester	Southampton	Newcastle	Watnall
1967	304 907	84 298	95 098	63 937	16 037	50 403
1968	347 267	83 728	108 838	73 433	41 097	60 101
1969	338 073	95 223	127 508	77 826	63 903	68 549

Grand totals: 1967, 614 680; 1968, 714 464; 1969, 771 082

There was, as usual, a variety of interesting demands for our services. The BBC 'weathermen' gave special television presentations in connection with the 'splashdown' of Apollos 10 and 11; personal briefings were provided by the officer-in-charge of Southampton Weather Centre for the competitors in the International Power Boat Race for the Wills Trophy and the Daily Telegraph Round-Britain Power Boat Race; the Southampton and Northern Ireland offices were asked for special forecasts in connection with safety measures for visiting nuclear-powered warships.

The number of letters received at Headquarters from the general public showed an increase during the year and averaged about 50 per month. They covered a variety of topics, ranging from an inquiry into the weather on a date in December 1942 for an article on the crash of a German bomber aircraft to a suggested meteorological explanation of the Loch Ness Monster.

There can be little doubt that public interest in the weather continues to grow and that the growth will pose new problems for the Office in the provision of services to meet all needs.

Services for civil aviation

The Civil Aviation Department of the Board of Trade is responsible for providing technical services for civil aviation. The provision of meteorological facilities is a technical service and is undertaken by the Meteorological Office as the agent of the Board of Trade. A meteorological services working group set up by the Board of Trade to study the provision of these services for civil-aviation users in the United Kingdom, including services to general aviation, has continued its investigations throughout the year and will report early in 1970. Representatives on this working group include members both from the Public Services and from the Defence Services Branches.

A Principal Forecasting Office at London/Heathrow Airport acts as the hub of forecasting services to civil aviation throughout the United Kingdom and also as European Area Forecast Centre for the North Atlantic. In this latter capacity it is responsible for the supply, to European users, of forecast weather charts suitable as documentation for flights from European terminals to North America as far as the Pacific coast, from Alaska to Los Angeles, and also to the eastern Caribbean. These charts are disseminated by land-line and radio-facsimile transmission to European users and also, together with similar charts for flights to European and Mediterranean terminals, to major civil airports in the United Kingdom over the internal civil-aviation meteorological facsimile network (CAMFAX).

In addition to the Principal Forecasting Office at London/Heathrow Airport, Main Meteorological Offices are maintained at Air Traffic Control Centres and in Northern Ireland, whilst subsidiary forecasting offices are

established at the major civil airports and observing offices at some minor aerodromes. Subsidiary offices are also maintained at four research and development aerodromes administered by the Ministry of Technology. Meteorological services for civil aviation overseas are provided at a small number of joint-user aerodromes (i.e. RAF and civil) in the Mediterranean area and at Bahrain and Sharjah. A detailed plan for a meteorological service in the Persian Gulf covering civil aviation in Bahrain and the Trucial States after the British Defence Forces have left in December 1971, was drafted for discussion by the states concerned. A meteorological service is also provided for many civil aerodromes by Meteorological Offices at neighbouring RAF establishments.

The range of commercial air transport operations continues to increase. During the year British Overseas Airways Corporation (BOAC) commenced direct non-stop flights from Heathrow to Alaska *en route* to Tokyo and also to Barbados in the Caribbean and the supply of digital meteorological data from the Bracknell computer (COMET) to BOAC was extended to meet flight-planning requirements for these new routes.

Appreciable use is now being made of the products of other European area forecast centres, namely, Frankfurt, Paris and Rome, in the preparation of suitable documentation for long flights extending beyond the area of responsibility of the London Area Forecast Centre.

Concorde 002 made its maiden flight from Filton to Fairford on 9 April 1969 and further test flights followed. Special forecasts for these flights were prepared at London/Heathrow Airport and transmitted by facsimile to the Concorde forecast unit at Fairford. Forecasts for flight-planning exercises for Concorde were also prepared every day at Heathrow for BOAC for the routes London–New York and London–Anchorage; these forecasts covered heights up to about 60 000 ft and included specially detailed information for the portion of the flight where the transition is made from subsonic to supersonic speeds.

Routine six-monthly calibration of runway lights, used in assessing runway visual range in foggy conditions, have continued throughout the year at most civil airports. An operational trial has continued at London/Heathrow Airport, during a few foggy spells since September 1968, to evaluate a system for the provision of slant visual range information to pilots on approaching to land whenever the runway visual range is less than 1100 metres; results have yet to be assessed.

An interdepartmental committee consisting of representatives from the Foreign and Commonwealth Office, the Board of Trade, the Ministry of Overseas Development, the Finance Branch of the Ministry of Defence, and the Meteorological Office was set up during the year to plan the requirements of a new international civil airport now being constructed at Mahé in the Seychelles. *Inter alia*, arrangements are being discussed for staffing and equipping a meteorological office at the airport with the capability of forecasting for routes to South and East Africa and to India.

The Meteorological Office was represented at joint meetings of the ICAO Sixth Air Navigation Conference and the WMO Extraordinary (1969) Session of the Commission for Aeronautical Meteorology held in Montreal during April 1969. These meetings were concerned with the needs of civil aviation in the *en route* stage. The requirements of all types of aircraft were considered with particular reference to supersonic transport aircraft in the 1970s.

Services for the Royal Air Force

Forecasting services are provided for the Royal Air Force by outstations which are distributed largely in conformity with the RAF organization. There is a Principal Forecasting Office at Headquarters Strike Command, and Main Meteorological Offices, functioning throughout the 24 hours, are located at convenient centres to control and advise subsidiary offices at RAF stations. At these subsidiary offices a forecaster is available at times which depend on the needs of the RAF. Some observing offices are maintained where there is no forecaster and the duties comprise the making of weather observations. At RAF Command Headquarters the meteorological unit usually consists of a senior officer of the Meteorological Office who acts as adviser to the Air Officer Commanding-in-Chief and as liaison officer between him and the Director-General of the Meteorological Office. The same general pattern applies in the U.K. and overseas in the Federal Republic of Germany and the Near East, Persian Gulf and Far East areas. There has been a gradual reduction in the number of meteorological stations necessary to meet the requirements of the RAF. In the U.K. this was accompanied by some changes in location and grouping. The Main Meteorological Office which has been at Mildenhall since 1935 was moved to a new location at Honington (between Thetford and Bury St Edmunds) and the Main Meteorological Office previously located at Uxbridge was moved to the London Air Traffic Control Centre, West Drayton. Staff limitations coupled with a shortfall in recruitment of the Scientific Assistant grade prevented the continued manning of one observing office in east Yorkshire.

Outstation meteorological services continued to meet the various requirements for the operation of RAF aircraft of all types ranging from those flying at high speed and high level to those with many hours' endurance at low levels. In order to meet the needs of the new type of aircraft being brought into service for maritime patrol, some changes in organization have been made involving the provision of facsimile and teleprinter links between the Principal Forecasting Office at H.Q. Strike Command and the meteorological offices at maritime bases.

A detailed study of the technical organization of the meteorological services provided for Strike Command and Air Support Command, with particular reference to the further development of computer and numerical forecasting techniques, has been completed and several of the recommendations have been implemented.

Changes were made to meet the requirements of RAF Commands at overseas stations within the general trend towards the greater use of computerized forecasts and forecasts received by facsimile. These changes have led to the Meteorological Office computer (COMET) at Bracknell largely supplying the forecasts of upper winds and temperatures on routes to the Mediterranean and Persian Gulf and to the establishment of an improved facsimile broadcast from Cyprus.

Suitably qualified local staff were recruited for the first time in Cyprus for assistant forecaster posts and in Bahrain for radiosonde duties.

At Gan (Maldives) a trial for using the RAF station as a shore station for collecting weather reports from merchant ships was put into operation. Overseas stations also took part in the Global Atmospheric Research Programme of the World Meteorological Organization for collecting aircraft observations in the

tropics and southern hemisphere during November 1969. Forecasts were also supplied by the meteorological office at Gan to the United States Air Force for Apollo space flights.

Meteorological officers continue to give regular courses of meteorological instruction at a number of schools in Training Command and at Operational Conversion Units. The second edition of the RAF Training Manual *Elementary meteorology for aircrew* was published.

Services for the Army

Four permanent outstations continued to be maintained at Army establishments for ballistic purposes. One of these stations, Larkhill, has now been in operation for 50 years. In addition, two subsidiary stations were manned during practice firings of guided weapons and conventional artillery.

As in previous years forecasts were provided for the Army Aviation Services.

Assistance and guidance were given in the training of the Royal Artillery Meteorological Section.

Meteorological advice and assistance was supplied to No. 1 (BR) Corps in Germany by a forecaster attached to that unit.

Liaison with the Navy Department

Close co-operation has continued with the Director of Meteorology and Oceanographic Services (Naval) on all aspects of the co-ordination of plans to meet the meteorological requirements of the defence forces both at home and overseas.

Services for the Ministry of Technology

The permanent outstation at Aberporth continued to serve the needs of the Royal Aircraft Establishment, Aberporth, and the Meteorological Office at Larkhill provided advice for the RAE range on Salisbury Plain.

Services to the Home Office

The meteorological requirements of the Warning and Monitoring Branch of the Home Office have been kept under review and detailed plans for meeting these requirements as effectively as possible in an emergency are maintained and tested in exercises.

International defence services

Within the framework of NATO, CENTO and SEATO, the three international defence organizations associated with treaties to which the U.K. is a signatory, there are meteorological planning committees on which the U.K. is represented. The work of these committees is to co-ordinate the meteorological support needed by the military forces in accordance with joint defence plans and, as necessary, to study the meteorological problems involved.

North Atlantic Treaty Organization

The twenty-sixth meeting of the Military Committee Meteorological Group took place in Brussels, Belgium, from 9 to 10 June under the chairmanship of the U.K. member, Mr P. J. Meade, Director of Services. Mr E. Evans was also present.

The Working Groups of the Military Committee Meteorological Group on Weather Plans and on Weather Communications met twice during the year; in Brussels, Belgium, from 19 to 27 March, when Mr E. Evans represented the U.K., and in Ankara, Turkey, from 15 to 22 October, when Mr A. G. Matthewman was the U.K. representative.

The Meteorological Panel (Panel XII) held a special meeting in Munich, Germany, on 12 and 13 June, prior to its ordinary meeting at the NATO Headquarters, in Belgium, from 16 to 20 June; Mr A. G. Matthewman attended both meetings.

The Interservice Working Party of the Military Agency for Standardization met in London, from 19 to 23 May. Mr K. Bryant attended as meteorological adviser to the U.K. delegation.

Climatological Services

The main function of the Branch is to provide information and advice about climate needed by the various sections of the community. The foundation of the service is the national climatological network of about 650 observing stations of various types. The majority of these stations are manned by voluntary observers and the Office takes this opportunity to thank them for their excellent co-operation in helping to maintain an efficient service. The Branch is responsible for the inspection of the network and for the collection, quality control, publication and preservation of surface and upper air observations made at stations in the United Kingdom. The surface observations are published in the *Monthly Weather Report* (MWR) and its *Annual Summary*, in the yearly publication *British Rainfall* and in other non-routine climatological publications. One of the main tables of the MWR is now processed completely by machine methods and the computer print-out is the copy passed to the printer. Plans are well advanced for automatic processing of another of the tables but complete automation of the MWR will have to wait for the installation of the new computer.

Developments in the application of climatology to industrial, commercial and social planning are continuing and this is leading to an increase in the number of complicated and diverse inquiries, especially from commerce and industry. Most of these inquiries require data to be processed and presented in the special form needed by the user. Thus the demands on computer facilities are continually increasing but problems are being tackled now which would have been impracticable, if not impossible, in pre-machine days. An example of this type of work is the production of bivariate frequencies of wind and rain for a selection of stations in the British Isles for use in the design and manufacture of windows and roofing. Another task was the computation of bivariate frequencies of temperature and humidity at about 60 stations; these data are used mainly for answering heating and ventilating inquiries. Requests for advice on the meteorological aspects of atmospheric pollution problems are also increasing. These inquiries are usually concerned with the atmospheric pollution associated with large works such as smelters, power stations, and refineries,

and advice is usually sought at the planning stage. World-wide interest in this subject is increasing rapidly and many scientists from other countries, such as U.S.A., India, Czechoslovakia and U.S.S.R., visited the Office to discuss problems.

As in previous years, there was an increase in the total number of inquiries with a marked rise of about 20 per cent in inquiries connected with the building and construction industry. This sharp increase was mainly due to an increased demand for design wind speeds and the introduction of the 'Climest' service in January. The 'Climest' service, which gives estimates of the duration of rain, low temperature and strong winds at any site, has been designed to assist the contractor to estimate the time lost because of adverse weather and thus help him to tender and plan for any contract. As usual, the inquiries covered a wide spectrum and included requests for climatological data in connection with research into the productivity of bees, the sales of a well-known beer, the sales of a well-known brand of soup and the testing of tyres. The Central Electricity Generating Board (CEGB) was supplied with wind data for nine stations in central England for its wind-tunnel studies of arrays of cooling towers and the Radio and Space Research Station was provided with climatological information for Bodmin Moor in connection with the erection of a 250-ft high radar dish at a site 950 ft above sea level. During a cold spell just after mid-March freezing rain occurred widely in the north Midlands and the southern parts of Yorkshire and Lancashire. There were heavy deposits of glazed ice and many telephone and power cables were brought down; the television transmitter mast at Emley Moor on the Pennines collapsed on 19 March 1969. A comprehensive report, on the weather during this period and the problem of ice formation on structures, was prepared for the Committee of Enquiry set up by the Independent Television Authority. Climatological data for this period were also supplied to the north-western region of CEGB for its investigation into transmission line failures.

While most requests are for information relating to the United Kingdom, the Office must also be prepared to answer inquiries about the climate of any other country. Data to meet this requirement are usually collected by means of an international exchange of processed material. Examples of these inquiries are the supply of wind speed and hurricane frequencies for the design of schools in Trinidad and Tobago and the provision of extreme wind speeds in Cyrenaica in connection with the design of a network of electricity distribution lines.

The Office continues to collaborate with other government agencies such as the Building Research Station, the Road Research Laboratory, the Warren Spring Laboratory and the Atomic Energy Research Establishment, Harwell. Information on the frequency of temperatures above certain threshold values was supplied to the Road Research Laboratory in connection with research into the laying of concrete or bitumen on roads. The Head of Branch continues to serve on the Interdepartmental Committee on Air Pollution Research and the Office is co-operating in the investigation of Tees-side mists. A senior officer continues to serve on the British Standards Institution Committee on wind loading; he also serves on three other technical committees dealing with certain aspects of wind loading. Lectures by this officer were included in the courses organized by the Building Research Station for architects and engineers.

Climatological services for Scotland and for Northern Ireland are provided by offices in Edinburgh and Belfast respectively. The demands on the two offices

continued to be high and in Scotland there were many inquiries connected with industrial development in the Firth of Clyde area. After discussion between the Office and the Scottish Development Department, a working party under the chairmanship of the Chief Planning Officer, Scottish Development Department was set up to review the sources of climatological data in Scotland and to make recommendations for improvements in the network.

Work continued on the collection and processing of ships' observations for the east Atlantic and the North Sea for the annual marine climatological summaries which will be published by the Office in accordance with an international agreement. The marine climatologist continues to represent the Office on the National Physical Laboratory Hovercraft Sea State Committee and he is also a member of the British Standards Institution Committee dealing with climatic hazards in the transport and storage of goods.

Hydrometeorology

The hydrometeorological work of the Office falls naturally into three sections: routine, inquiries and investigations. The routine covers regular collection, scrutiny, processing and preservation of rainfall data for the U.K. Most of the data are collected from voluntary co-operating stations maintained by private individuals, water supply undertakings, local authorities and river authorities. Regular inspections are made to ensure the maintenance of required standards of site, instrumentation and observational procedures, and 740 stations were visited during the year. The Edinburgh Office administers and inspects stations in Scotland, handles their data and deals with local inquiries, whilst the Belfast Office has similar responsibilities for Northern Ireland. Rainfall data are published in the *Monthly Weather Report* and in *British Rainfall*, and from time to time in non-routine publications and branch memoranda. In particular, the year saw the completion of the texts of *British Rainfall* for 1962, 1963 and 1964 and for the first five-year supplement to *British Rainfall* for the period 1961–65.

In the inquiries section the steady increase in inquiries handled, apparent for many years now, continued. The number of inquiries was about 8 per cent greater than in 1968. Most of the inquiries again came from the legal profession and insurance companies or from the building and construction industries.

Many of the major inquiries of the year arose in connection with Section 14 of the Water Resources Act of 1963. This section of the Act requires that hydrological surveys of a river authority's area be made every seven years and the date of completion of the first survey was set for 1969. The advice of the Office was sought by many of the authorities on aspects of rainfall, evaporation and soil moisture deficit. For the Thames Conservancy, estimates of average and month-by-month rainfall and potential and actual evaporation for the period 1956–67 were supplied for 25 aquifer units in the Thames basin. As with all work on specific catchment areas, a detailed study of land use in each aquifer unit was carried out for the derivation of actual evaporation from the potential, allowance being made for seven different vegetation and cover types and, where necessary, for the proportion of urban area and open water. Similar work was carried out for other river authorities and for the Institute of Geological Sciences.

The work initiated in 1968 for the Morecambe Bay Feasibility Study was completed during the year. In connection with flood studies over the area draining into Morecambe Bay, estimates were made of daily areal precipitation, potential and actual evaporation, soil moisture deficit and effective precipitation (the precipitation contributing to surface run-off or permanent ground water). An innovation in the model for deriving actual evaporation from potential evaporation was the incorporation of an allowance for run-off from precipitous slopes. The day-by-day estimates were made for seven catchment areas over a period extending from 1910 to 1967; as a daily series they are unique for a period of that length and are proving of great value to the consulting engineers engaged in the study. Additionally, estimates were made of the likely amount of evaporation from the body of water to be impounded by the barrage, allowance being made for seasonal variation of the temperature and volume of the impounded water and the temperature of inflowing water.

In connection with the Lambourn Valley pilot scheme of the Thames Conservancy's plan to exploit the ground water of the Thames basin, estimates of monthly rainfall and potential and actual evaporation were made from 1920. The data are to be used to deduce recharge to underground strata over a long period. Estimates of average annual rainfall in connection with proposed water supply schemes were provided for areas in the southern Pennines, southern Scotland and parts of Somerset, Devon and Sussex; in some cases estimates of evaporation were also provided.

The Office continued to issue maps of soil moisture deficit at fortnightly intervals beginning in early summer and good progress was made in assessing 25 years' (1941–65) end-of-month soil moisture deficit values for a number of stations in England and Wales. These data will be of value in the U.K. flood studies now getting under way. The issue of weekly estimated soil moisture deficits in connection with operational procedures for spraying potatoes proved so successful in 1968 that a wide extension of the network was asked for in 1969.

A map of average annual potential evaporation was completed for England and Wales. The map, for which there was an urgent requirement in connection with the building and construction industry, is based on simple extrapolations of evaporation with altitude and is necessarily uncertain at higher levels; as more data become available at higher levels important modifications in the map may be expected.

Major work started for the Water Resources Board included a study of the ground water resources of the chalk in the Great Ouse basin and estimation of evaporation from Lough Neagh.

The investigational section continued to be actively involved in the expansion of effort being put into the science of hydrology, both nationally and internationally. It maintained its close liaison with the Water Resources Board and river authorities, particularly in respect of rainfall and evaporation networks for river authority hydrometric schemes. Much of this development work was carried out through membership of the Board's Instrumentation and Data Group and its sub-groups. Particular attention was paid to river authority needs for rainfall and evaporation data from automatic and conventional instruments, and the development of automatic instruments and telemetry systems. This work culminated in recommendations for a co-ordinated data-processing system in England and Wales, involving river authorities, the Water

Resources Board and the Meteorological Office and handling rainfall, evaporation and hydrological data. The system entails the flow of data from individual river authorities through regional centres to a national computer complex and includes quality control. River authorities will have direct access to the computer complex for processing of data and for retrieval from store of observational and processed data. Further progress was made, in co-operation with the Water Resources Board, the Dee and Clwyd River Authority and Plessey Radar Ltd towards implementing the radar project associated with the Chester Dee regulating-reservoir research programme whereby it is hoped to measure areal rainfalls over sub-catchments by means of a 10-cm radar. Full operations should begin in the summer of 1970.

The floods of July and September 1968 in England were the subject of further investigations. More attention is now being paid to detailed study and analysis of areal as opposed to point rainfalls and advanced computer programmes are being written. Towards the end of the year, the study of river floods in the United Kingdom as recommended by the Institution of Civil Engineers was started with the appointment of a Principal Scientific Officer to lead the meteorological studies in parallel with the hydrological work to be performed by a team at the Institute of Hydrology. The aim of the study, for which a large proportion of historic British rainfall data will be required in a form suitable for computer processing, is to provide civil engineers and river authorities with much more soundly based knowledge of river flooding and its potential, for use in providing more economical and efficient flood protection schemes. Inquiries on rainfall intensity/duration frequencies continued at a high level from engineers concerned with motorway and urban storm-water drainage and drainage for factory sites.

Whilst studies of flood-producing rainfalls are gathering momentum the serious deficiencies of rainfall in certain parts of the country in 1968 and 1969 have drawn attention to the fact that this country is not immune from problems of drought in relation to the development of water resources. A start has been made on the investigation in greater detail of this relatively neglected end of the rainfall spectrum.

The Senior Scientific Officer attached to the Institute of Hydrology has continued his research work on evaporation from forests. Close liaison was maintained with the Institute on other matters of mutual interest, especially on problems concerning the accuracy of point-rainfall measurements and on possible snow-hydrology studies.

The Office is co-operating with Gloucestershire local authorities and Bristol University in a study of drainage problems arising from continued urbanization of the lower left-bank plain of the River Severn. Advice has been given on rain-gauge networks and help in implementing them, and advice will be given on the analysis of the data. The rainfall side of the work is in many ways similar to the Winchcombe rainfall experiment but the dimensions of the networks will be ten times larger and coarser than those of the Winchcombe experiment. This study will bridge the gap between short-duration rainfall statistics used in urban storm-water drainage design and the more familiar statistics derived from daily rainfalls.

Two hydrometeorological studies were undertaken for British consulting engineers working at overseas sites. A study of meteorological conditions giving rise to flooding on the River Yom, northern Thailand, has yielded estimates

of extreme rainfall over the catchment area which will be used by the engineers for the design of the proposed dam spillway. Evaporation analyses have also been carried out to assess the agricultural potential of the surrounding country once the proposed dam is in operation and irrigation water available. A similar study for the mountainous Lar catchment, northern Iran, was complicated by a snowmelt component in the flood run-off. Separate analyses of snowmelt and rainfall flood events were necessary in this case. The information will be used for dam spillway design in a project to improve water supply to Tehran.

The Office continued to contribute to the work of the Hydrology Committee of the Natural Environment Research Council and to be represented at national level in the work of the International Hydrological Decade. Two delegates were sent to the mid-decade conference in Paris in December where the future programme of the decade and a long-term plan of action for international co-operation in hydrology were discussed. The branch also contributed to international co-operation in hydrometeorology by supplying the chairman of one working group and members of two other groups of the Commission for Hydrometeorology of the World Meteorological Organization. Comparison tests of evaporation tanks have continued as part of the world-wide investigation organized by WMO.

Services for Agriculture

A very full year's activity included completion of scientific work on foot-and-mouth disease; papers by three members of the staff have now been printed, or await publication. A plan for full participation in any future outbreak was arranged between the Office and the Veterinary Service of the Ministry of Agriculture, Fisheries and Food, which would involve detachment of Experimental Officer and Scientific Assistant staff from the Office. Important lines of research at Bracknell included investigations concerning the effect of weather on hop yields and quality, milk production and quality, and certain animal diseases. Research has also been made into soil moisture deficits in autumn, and on excess winter rain and leaching. Work was completed on a review of trajectory possibilities to Great Britain from Europe since the Second World War in connection with possible transfer of spores and insects, and a new project has just started on weather and watercress crops. Miscellaneous work of a non-research type included lecturing to a Voluntary Service Overseas course at Reading University, lecturing to horticulture students at Wisley, and land classification in the south-east of England.

Outstation research has included looking into ventilation and storage problems of potatoes, consideration of glass-house design and location, mulching and soil temperatures, and the effect of slope and aspect in land classification. Work continued on climatic effects in apple growing, estimation of long-term irrigation needs, and experiments relating plant growth with weather, to name a few representative topics.

International co-operation has continued at a high level. There have been few overseas meetings, but two branch members attended the International Biometeorological Congress at Montreux. One of them gave the opening paper on the first day, and the other was co-chairman of a Study Group. International

work included the performance of rapporteur services for the World Meteorological Organization on meteorology and the Colorado potato beetle, on indoor climates for housed animals, on plant protection against adverse weather, on minimum temperatures at the surface, and on weather and animal diseases. A WMO *Technical Note* on the epidemiology of wheat rusts was issued in the name of a working group chaired by a branch member. Finally, one member of the staff, President of the WMO Commission for Agricultural Meteorology, attended various meetings (UNESCO etc.) in this capacity in Geneva and Paris during the year. Other meteorological meetings in the United Kingdom at which the branch was represented included a shelter symposium in Cambridge and a biological symposium in London.

Many lectures at various levels have been given by several members, ranging from a British Association meeting to farm study groups. Nearly 20 published papers appeared during the year, and nine members of the staff wrote a total of 35 agricultural memoranda, one or two of which were written in conjunction with outside authorities. Close co-operation has continued with the various research establishments, with universities, and with National Agricultural Advisory Service Regional Headquarters and research laboratories; a number of inquiries from individual farmers, students, etc., were also dealt with.

An Assistant Experimental Officer in the branch has been granted leave of absence in order to study for a degree in agriculture at University College of North Wales, Bangor.

Marine Branch

The basic work of the Marine Branch is, in the words of the International Convention for the Safety of Life at Sea, 'to encourage the collection of meteorological data by ships at sea and to arrange for their examination, dissemination and exchange in the manner most suitable for the purpose of aiding navigation'. The coming of the meteorological satellite and the upper air observation have in no way diminished the need for surface observations from the open oceans which occupy three-quarters of the world's surface. The nautical organization is in the charge of a Marine Superintendent at Headquarters with supporting staff who deal with the overall arrangements and are responsible for the collection of the data and the initial steps in its processing. There are also Master Mariners at the principal ports in the U.K. to supply, replace or withdraw instruments in voluntary observing ships and to recruit and encourage additional ships.

Except in ocean weather ships, which are fully equipped meteorological stations, meteorological work at sea in British merchant ships has always been done on a voluntary basis. Personal contact between the Marine Branch and observers at sea has been maintained by visits of Port Meteorological Officers to ships and by correspondence with shipmasters as each meteorological logbook is received. Shipmasters and officers are also encouraged to visit Headquarters when on leave. Voluntary observing ships also receive a copy of a quarterly journal, the *Marine Observer*, which is a valuable means of keeping observers interested in the work. Experience over the years has shown that this system works well and maintains a generally high standard of observations from all types of ships.

Voluntary observing ships are supplied with the necessary instruments on loan and make observations every six hours wherever their voyages take them. As many as possible of these observations are transmitted by radio to the most convenient coastal radio station, and are addressed to the meteorological service responsible for the area through which the ship is passing (e.g. ships in the eastern North Atlantic send their reports to the British service through GPO coastal radio stations). The number of radio weather messages so transmitted must largely depend on the number of radio officers carried in a particular ship (the majority of British ships carry only one) and whether the synoptic hour falls within a period when the radio officer is on duty. But shipmasters are becoming increasingly aware that a ship's observation can be of considerable use to a meteorological service (thus contributing to the safety of the ship) even if transmission has to be delayed until watch is resumed, and the proportion of messages sent to observations made shows a satisfying increase. It is not uncommon also for a radio officer to break into his off-duty time solely for the purpose of sending a radio weather message.

The problem of recruiting 50 extra ships every year for the next few years as part of the U.K. contribution to the World Weather Watch (WWW) is an exacting one in the face of a numerically shrinking Merchant Navy, brought about firstly by a building programme of larger and faster ships, and secondly by the gradual replacement of conventional cargo ships by container ships (in shipping circles it is confidently expected that eventually 9 container ships will be able to do the work of 80 conventional ships). It is not only a problem of recruiting new ships but also of finding replacements for ships which are being sold or broken up and Port Meteorological Officers throughout the year have been fully extended on this work. In the first six months of 1969 for instance the size of the voluntary observing fleet, carrying instruments, increased by only 7 ships but this modest increase in numbers involved 55 movements of a complete set of instruments, i.e. 24 ships were withdrawn and 31 were recruited. The problem has been somewhat aggravated by contractual difficulties concerning the supply of instruments, by the gradual changeover from Fahrenheit to Celsius thermometers (which is not yet complete), and by the long-hoped-for but disappointingly slow changeover from marine mercurial barometers to the precision aneroid.

An increasing number of British ships are sold to foreign shipping companies or to shipbreakers during their outward voyages, and the recovery of Meteorological Office instruments from them is often a problem. The Maritime Branch is much indebted to many Commonwealth and foreign Port Meteorological Officers who, often at very short notice, have removed the instruments, and to the many shipmasters who have brought them home.

During the year awards of books were, as customary, made to the masters, principal observing officers and senior radio officers of the 100 ships who sent in the most carefully kept meteorological logbooks during the year. Similar awards were made to the masters and officers of four vessels in the short sea trades for their contribution in making sea temperature observations and to five trawler skippers and radio operators who had the best records in making and sending non-instrumental observations from the Arctic. Barographs were presented to the four shipmasters whose long records and consistently good service were considered as deserving special recognition.

The British Weather Ships completed 22 years' service in the North Atlantic during the year; the present four ships have now been operating for about 10 years and continue to give good service. These ships co-operate with French, Netherlands and Norwegian vessels in maintaining four ocean weather stations in the eastern North Atlantic, while a number of other countries make financial contributions towards the cost; weather ships of the U.S. Coast Guard similarly man four stations in the western Atlantic. All these ocean stations are constantly manned, and hourly surface and 6-hourly upper air observations (radiosonde and radar wind) to an average height of about 65 000 ft (19·5 km) are transmitted by radio. In addition the British ships make observations of global solar radiation and radiation balance, of sea temperature and salinity at various depths down to the sea bed, and of magnetic variation. Deep echo-soundings are made, and some marine biological work, including plankton sampling and squid fishing, is regularly done.

Communication facilities and routine navigational aids were provided for transatlantic aircraft by all the British ships, and air/sea rescue equipment was kept in a constant state of preparedness. Comprehensive search and rescue exercises were frequently carried out in which RAF aircraft sometimes participated.

The Marine Branch worked closely with the Board of Trade in fitting out the trawler support vessel *Orsino* for duty on the fishing grounds north of Iceland from 1 December to 30 April. Trawler skippers were very glad of the weather advice they received from the support vessel which was based on the local weather forecast prepared by the meteorologist on board and the weather forecasts received from Bracknell and Iceland. The *Orsino* resumed duty as a support vessel on the fishing grounds north of Iceland on 1 December.

The Marine Branch has continued to work closely with the Central Forecasting Office in the weather routeing of ships on the North Atlantic and in the provision of ice charts. There has been a welcome increase in the number of ice reports received from civil aircraft during the year, mainly from those on polar routes. Improved satellite photographs have been very useful in determining the distribution of ice.

Some 30 000 observations of surface ocean currents were extracted from ships' logbooks during the year and entered on punched cards. Quality control of these observations by computer was continued and ocean current data were supplied to the Navy Department for new Routeing Charts of the Indian Ocean. The ocean-current and sea-ice sections of six volumes of Admiralty *Pilots* were revised during the year.

There was an increase in the number of marine inquiries, most of them from solicitors, shipping companies, universities and industrial firms.

New editions of the *Marine observer's handbook* and the *Marine observer's guide* were published during the year and publication of the *Marine Observer* each quarter continued as usual.

Instruments and Observations

For the Instruments and Observations Branch the year was characterized by the very wide range of projects pursued. On the development side no new major tasks were progressed to any significant extent. The main effort was devoted to the consolidation and, in some instances, introduction into routine use, of

developments of previous years. The full range of 'services' has been maintained and activity in the various sections of the branch has been at a high level. The detailed planning, in conjunction with the Ministry of Public Building and Works, of the new branch accommodation at The Experimental Site near Bracknell has been an interesting but time-consuming activity.

Instrument development

On the 'surface' instrument side, as a result of earlier 'in-house' development work, a group of projects reached the stage where contracts for the manufacture of equipment could be placed with outside firms. Examples of these projects are automatic range-change devices for electrical anemographs; static pressure heads for use on ships, buoys and badly exposed land sites; automatic dew-point hygrometers for use as working humidity sub-standards; precision equipment for generating known humidities; and lithium-chloride humidity elements for the remote recording of humidity at operational stations.

A second group of projects, no one of which was in itself major, but which in total absorbed considerable effort, has been advanced. Some projects which were commenced within the year have already reached the operational prototype stage at which field trials are being conducted. Among these are a runway cross-wind resolver in which the direction of the runway in use can be set by the air traffic controller; a system for telemetering wind data to a number of reception points; a converter to change d.c. to frequency-stable a.c. for supplying ship-borne instruments; a fluid-damped wind vane for automatic weather station use; a servo-following type of pressure transducer.

A further group of tasks has involved design improvement to existing instruments and systems. Examples are modifications to the transmissometer system to give closer compatibility with telemetry links and to permit the display of time-averaged determinations of optical range both locally and remotely; improvements to the tipping-bucket rain-gauges which are now in use at a number of stations for making hourly synoptic reports of rainfall; design changes to anemometers to render them gravity independent, for use on buoys.

Towards the end of the year financial approval was received for the purchase of 10 automatic weather observing systems which will be used for operational trials at a variety of locations in this country.

On the 'upper air' side, work towards the operational introduction of the Mk 3 radiosonde has absorbed most of the available effort. The experience gained in trials has been incorporated into a set of production drawings and arrangements have been made for the manufacture of the first 100 models to prove these drawings. The opportunity was taken to make refinements to the signal pattern to render it more suitable for application to automatic computing machinery. Computer programming routines have been under active development; in particular, solutions to two problems which are fundamental to successful automatic data processing have been found and proved.

For immediate operational purposes the further manufacturing development of British-made synthetic rubber balloons has been actively encouraged. Balloons of this type are now in use for more than half of all routine upper air soundings and the enhanced performance so achieved is reflected in the statistics presented in Table V. We look forward to further improvement in heights attained as development progresses.

In the latter months of 1969 consideration was given to the feasibility of using navigation aids (LORAN C and OMEGA) for upper wind finding from ships at sea, and to the best way to integrate such a system with conventional upper air observing methods. Developments are expected in the coming years. A preliminary study was made of the possibility of using constant-level balloon-borne platforms, carrying pressure and temperature sensors of the Mk 3 sonde type, combined with interrogation and location by the proposed U.K. meteorological application satellite, X-4. Finally the present equipment used for receiving APT cloud pictures from U.S. satellites was successfully modified to receive night-time infra-red cloud images from NIMBUS III.

The mechanical workshop has continued to provide a construction service to the research branches of the Office as well as to the Instruments and Observations Branch itself. The quantity and quality of work demanded has been high and at times branches have had to seek assistance from other organizations solely on the grounds of the limitation set on output by the number of staff employed. Reorganization of the electronic workshop was put in hand. It is hoped to arrive at an organization parallel to that of the mechanical workshop but full achievement will only be possible following occupation of the new premises at Easthampstead.

Observational techniques and operational trials

Assessments of the field performance of various instrumental developments have been made, and appropriate techniques for their operational use have been devised. In some instances design modifications have been suggested to overcome weaknesses revealed by field trials. Particular attention has been paid to the performance of rain-gauge collectors, including their automatic indicating and recording mechanisms.

Questions of the general technique of measurements and the validity of observations have been examined; in particular, special attention has been given to the difficult field of visibility.

Equipment installation and technical liaison

The year, particularly the second half, was a busy one for the installation staff. Five major radar installations were completed. Four of these were weather radars, the fifth being a 10-cm wind finder. All were at overseas locations and three of the weather radars were fitted on behalf of the Ministry of Overseas Development.

Twenty-one cloud-base recorders have been installed at U.K. sites. Four of these were telemetered versions which required modification before fitting. Four transmissometers were similarly modified and are now in operational service.

The first two medium-pressure electrolytic hydrogen generators were installed. The first went to the upper air station at Stornoway where the installation was undertaken in co-operation with the equipment manufacturer. The second was allocated to the upper air station at Hemsby where fitting was carried out by our own staff.

Throughout the period there was detailed liaison and planning with the Ministry of Public Building and Works, particularly for the installation of new radars at Masirah, south Arabia, Newcastle and Manchester and for further

hydrogen generators at home and overseas. Assistance was also given to the Ministry of Overseas Development in connection with arrangements for the installation of a 10-cm weather radar in East Pakistan.

Approval in principle was obtained for the purchase of additional 10-cm and 3-cm wind-finding radars to complete the replacement of old radars dating from the Second World War which are in use at some upper air stations. As a further move towards the use of automatic computational methods, this approval also covered the provision of equipment to provide digital output of target range, elevation and azimuth for these and previously acquired radars of the 10-cm type.

Technical liaison with manufacturers in connection with existing and proposed equipment production contracts continued. Considerable effort was made to improve the documentation associated with the installation, maintenance and use of equipment. Because of the ever-present shortage of appropriately qualified staff, outside contractors were again employed to do much of the drawing office work. Critical reconsideration of the design of established instruments was continued as far as available effort allowed.

Instrument testing and calibration

Table XV shows the number of instruments tested or calibrated. During the year the Test Room was moved to new accommodation adjacent to the main stores area. The move was effected with very little disruption of the flow of work. The standards room in the new accommodation is now air conditioned. This is a marked improvement as compared with the previous arrangements.

Some difficulty has arisen in connection with the manufacture and subsequent submission for acceptance of traditional equipment by firms new to this field. Many find it difficult to meet our specified requirements and this has resulted in a disturbing number of cases of multiple submission before acceptance, according to contract terms, was possible.

The Mk 2 radiosonde calibration plant continued to function at the required capacity. Some progress has been made with the design of the new Mk 3 plant, but this was set back by uncertainties over accommodation availability. A small humidity-sensor calibrator for eventual use at radiosonde outstations (when the Mk 3 sonde is introduced into service) was constructed and is now under test prior to specification and manufacture in small numbers.

The usual facilities were provided for the instruction of visitors, some from overseas countries, in the methods of instrument testing and calibration. Work for outside authorities was continued as demands arose.

Thunderstorm location

The home and overseas CRDF network, controlled from a central station at Easthampstead, continued to function as in previous years. However, observations at 00 and 02 GMT were discontinued from 1 March so that staff numbers could be reduced, following the integration of CRDF staff with radiosonde staff at the four U.K. outstations. The usual number of inquiries was received from outside bodies. Data were provided and/or special observations made in so far as effort was available.

Surface observations

In the United Kingdom, 79 surface observing stations report in international code every hour, day and night, throughout the year. A further 49 stations report every 3 hours. In addition 132 stations report at various times during each day of the year. Of this total of 260 stations, 107 are manned by full-time professional staff and 153 by voluntary observers most of whom have attended the Meteorological Office Training School course on observing.

Reports in plain language are received from 17 town offices of the Automobile Association, 21 Police or Fire Service Stations and 31 Road Maintenance Depots located alongside motorways.

Upper air observations

The network, consisting of eight U.K. stations, seven overseas stations and four Ocean Weather Ships, fulfilled the normal programme of observations throughout the year. Rather more than 98 per cent of the possible routine work was successfully completed in spite of reduction in staff complements and shortfalls of trained staff below the reduced complements. Assistance was given to other branches of the Office and to other organizations in support of investigational work in so far as available staff numbers allowed.

It is pleasing to report that there has been an improvement in balloon performance and hence an increase in the average heights to which observations have been made.

Considerable help was given in the planning of the new upper air stations at overseas locations. These are to be set up as part of the World Weather Watch programme.

A single meteorologist successfully launched radiosonde ascents from a merchant vessel for about six months of the year. It is hoped that the programme will be extended as soon as resources allow. The station at Nicosia, Cyprus, was transferred to a new building at Episkopi during July. New buildings were also completed and occupied at Stornoway and Masirah.

Regional servicing organization

This organization continued to run fairly smoothly throughout the year. Much of the work consists of the preventive maintenance of operational equipment. This is an essential but rather unglamorous task. Its justification has been fully shown by the serviceability record of most field equipments.

Newly recruited and trained staff continue to be absorbed as fast as they become available.

Training

Attachments of students from overseas sponsored by the British Council and World Meteorological Organization were up to the usual numbers. Several university vacation and sandwich students were given training and opportunities to acquire experience in the development laboratories. The Branch continued to staff and run the radiosonde training school at Hemsby and the technician school at the Experimental Site, Easthampstead Park, near Bracknell.

Computing and Data Processing

Computing and data-processing services are centralized in one Branch, Met. O. 12, which operates the computing laboratory and punched-card installation and also provides a programming and consultancy service for all other branches of the Office. Technological advances in computers, data processing and associated equipments continue at a very rapid pace. It is an important responsibility of the Assistant Director in charge of the Branch to keep generally abreast of developments so that advances with potential applications to the Office may be more fully investigated and appraised. Training courses in computer programming have been provided by staff members of Met. O. 12 for a wide range of staff from many branches.

Punched-card installation

This installation is equipped with a range of modern punched-card machines, including automatic punches and verifiers, sorters, collators, tabulators, tape-to-card converter, etc. Since it was set up in 1920, a library of over 53 million standard 80-column punched cards containing surface and upper air data from land and marine stations and surface data from voluntary observing ships has been accumulated. The present punching rate of British data is about one and a half million cards a year and about a further one million cards of selected foreign data are obtained through international exchange. The Office has continued to utilize spare capacity at other governmental punched-card installations.

Punched-card machines are used for the simpler jobs of data processing which do not involve much calculation, such as frequency distributions and listing and tabulation of data, whereas the larger computing tasks from data on punched cards are programmed for and carried out on the KDF9 computer.

COMET computing laboratory

The laboratory is equipped with an English Electric KDF9 electronic computer which was installed in the summer of 1965. Within the Office the computer is known as COMET. The computer is able to run up to four programmes simultaneously (i.e. it has a multiprogramming facility). Its high-speed random access memory consists of 24 576 (48 bit) words and it also has a magnetic drum which provides a further 40 960 words of backing memory. Other standard peripheral equipment consists of six magnetic-tape units, three paper-tape readers, three paper-tape punches, one high-speed line printer, and one punched-card reader. A variplotter, manufactured by Electronic Associates Limited, has been installed as a special 'on-line' peripheral device sharing a peripheral channel with one paper-tape punch. The laboratory also contains ancillary rooms with a range of tape-editing equipment for punching of data and programme tapes and for 'off-line' printing from paper tape.

One of the main tasks carried out on the computer comprises operational numerical forecasting runs at fixed times. Between seven and eight hours a day are devoted to this work during four periods of intense computer activity. These numerical forecast runs consist of large programmes which occupy substantial parts of the immediate access and magnetic drum backing stores and also keep the central processor busy for much of the run. Nevertheless, by a judicious choice of suitable programmes to mix with the forecast run it is

possible to use the computer in the multiprogramming mode throughout much of the forecast runs. Other important tasks are computations for research projects and for parts of the long-range weather forecasting routine, routine data processing (e.g. checking and processing rainfall data from about 6500 stations in the United Kingdom) and the preparation of tabular material for certain publications, e.g. *British Rainfall.* The build-up of a comprehensive general-purpose library of meteorological data on magnetic tape has continued. Further developments were made to the programmes which control the line-drawer and permit the automatic production of isopleths on meteorological charts from values at grid points computed by the numerical forecast routines. A workable operational routine which produces a selection of line-drawn charts of acceptable quality has been introduced and is run regularly to fixed schedules. Rather more than 50 such charts are produced each day. Some experimental work was carried out using the line-drawer for superimposing isopleths of wind speeds on contour lines and thereby producing charts of potential use for aeronautical purposes.

Throughout the year the computer has been operated round-the-clock except for periods of routine maintenance which currently aggregate 16 hours a week. On the whole serviceability has been good but there was one period when a number of computer faults proved difficult to trace and eradicate. This period culminated with much unserviceability lasting a few days and it was necessary on two successive occasions to utilize an emergency stand-by computing facility which had been pre-arranged for such an occurrence. The stand-by arrangements worked well and the computing services for numerical forecasting were maintained as planned. The stand-by machine used on these two occasions was the KDF9 at the Defence (Navy) Research Laboratory, Teddington, and the staff at Teddington were most co-operative and helpful. During most of 1968 the work load for COMET had been very close to its capacity but during 1969 it became evident that the computing requirement exceeded the installed capacity. To provide some early increase in computer capacity arrangements were made with the Defence (Navy) Research Laboratory, Teddington, to use their KDF9 on some nights. Staff are provided by the Office and suitable work is taken to Teddington on two successive nights each fortnight. This provides a welcome addition to our computing capacity but a full solution to our growing needs for computing depends on the acquisition of a large new computer.

Other activities present and future

Development work on the prototype automatic plotter for producing weather charts ceased.

Some additional staff joined the branch during the year to aid senior staff to prepare for the new very powerful computer, e.g. in planning the several systems which are a Met.O.12 responsibility and need to be implemented on the new computer. Work on the acquisition of the new computer—preparation of several reports leading up to formal invitation of tenders by Her Majesty's Stationery Office in August, appraisal of these tenders during September and October and subsequent high-level consideration—was rewarded just before the year's end when HMSO were given authority to acquire an IBM 360/195 machine for the Office by October 1971. This machine is the most powerful presently being made by IBM.

Meteorological Telecommunications

Meteorological telecommunications are indispensable in the provision of meteorological services. Meteorological observational information has to be collected and distributed, and meteorological processed information, such as analyses and forecasts, has to be disseminated. It is a simple fact that the atmosphere knows no frontiers and no country can be truly meteorologically independent of international co-operation in the provision of its meteorological services. Collection, distribution and dissemination of meteorological information is required both nationally and internationally and, for the most part, the only effective means is by telecommunication.

The organization of meteorological telecommunications in relation to international aspects is co-ordinated by the World Meteorological Organization so that the needs of all its Members for both observational and processed information can be met to the best advantage. The United Kingdom as a Member of WMO has certain specific international responsibilities for the collection and distribution of observational and processed information.

The Meteorological Telecommunications Centre (Met.T.C.) at Bracknell has a commitment to collect reports of meteorological observations made in the United Kingdom, the Republic of Ireland, Iceland and Greenland, and of those made by four ocean weather stations in the North Atlantic. It is also a reception centre for reports of observations made on merchant ships and on aircraft. The Centre has to transmit all these reports for international dissemination. It also has the responsibility to provide a radio-teleprinter broadcast of observational information relating to the European Region. The area of required reception embraces the European continent, North America, the northern half of Africa and western Asia.

Internationally the United Kingdom has a responsibility to provide radio-facsimile broadcasts of pictorial information. There are two such broadcasts which carry between them processed information from the WMO Regional Meteorological Centre at Bracknell and from the ICAO North Atlantic Area Forecast Centre at London/Heathrow Airport. Additional international requirements for processed (pictorial) information from the United Kingdom are met through land-line facsimile facilities connecting Bracknell with Offenbach, Paris, De Bilt and Copenhagen.

As regards national requirements, Met.T.C., Bracknell, is responsible for the collection and distribution of meteorological information (both observational and processed) to meet the needs of the meteorological services centred at Bracknell and the needs of the meteorological offices throughout the country. The coverage of observational information collected is the whole of the northern hemisphere, the density of coverage being greatest over the United Kingdom and adjacent areas. Collection and distribution of this observational information is largely by a data telegraph land-line system. Processed information is usually in pictorial format and its distribution is by land-line facsimile facilities.

During the year the fullest use has been made of meteorological satellite facilities. Day-time observational pictures from orbital satellites are supplied in real time through the receiving system of Met.T.C., Bracknell, to the Central Forecasting Office at Bracknell, the Principal Forecasting Office at London/Heathrow Airport, and five other important outstation meteorological offices. Read-outs of night-time satellite observations are also received and the pictures passed for operational use to the Central Forecasting Office.

Operation of the telecommunications organization continued at a high level throughout the year. There were also intensive efforts directed towards the implementation of the systems design study for the automation of the national telecommunications facilities as a major component of a world-wide meteorological system. These activities and their objectives form the subject of the Special Topic (page 1).

International and Long-term Planning

The international character of meteorology inevitably leads to a number of international conferences each year. Many of those in which the Meteorological Office is concerned are held under the auspices of one or other of three intergovernmental organizations. The World Meteorological Organization (WMO) deals with the international aspects of the organized practice of meteorology and its applications to human activities. The International Civil Aviation Organization (ICAO) deals with international questions affecting civil aviation, and many of its meetings are concerned directly or indirectly with the meteorological aspects of civil aviation. In addition, various aspects of meteorological support for the armed forces of the North Atlantic Treaty Organization (NATO) are discussed at meetings of committees and working groups set up for that purpose. There are also meteorological committees associated with the other international military organizations in which the U.K. is concerned.

A number of other meetings are organized by one or other of the constituent bodies of the non-governmental International Council of Scientific Unions (ICSU). The various bodies included in ICSU are each concerned with the promotion of one or other of the sciences or spheres of scientific interest, such as outer space, the oceans, the Antarctic, especially as regards international requirements. Meteorology has a part to play in several of these, and the Meteorological Office is a member of several of the corresponding British National Committees.

Delegates and representatives from the Meteorological Office at these various meetings are drawn from all parts of the Office according to the subjects to be discussed. An account of the principal meetings attended will be found in the 'International Co-operation' section (see page 67).

The Foreign and Commonwealth Office, the Ministry of Overseas Development, and other government departments regularly require advice or comment on administrative, financial and technical aspects of meteorological matters which arise in the general international field, particularly with respect to United Nations and WMO activities.

The Director-General is Permanent Representative of the U.K. with WMO. U.K. Dependencies are included with the U.K. except for those which, having their own meteorological services, are Members of WMO on their own account (Hong Kong, British Caribbean Territories). The Director-General is an elected member of the WMO Executive Committee in a personal capacity. The Assistant Director (International and Planning) assists him in this work, and acts as the usual channel of communication with WMO on behalf of the Permanent Representative. Much of the work of WMO is carried out by the Members, the Secretariat acting as co-ordinator, so that as the international development of meteorology continually expands so the volume of work falling to the Members also expands.

Detailed elaboration of certain aspects of the World Weather Watch Plan especially in respect of the need for distribution of processed data from Regional Meteorological Centres, procedures and responsibilities for the storage and retrieval of meteorological data, and the global and regional telecommunications system, were major concerns internationally during the year. The strain on WMO machinery caused by the advent of WWW, and the need for more rapid and integrated action by the Organization in response to the actions of other international bodies, have prompted a study, which is still in progress, as to whether any changes are needed in WMO's structure and methods of work.

Plans for setting up new upper air observing stations on some Pacific islands in conformity with the WWW Plan have been developed further. In particular, the proposal to set up one such station in the New Hebrides Condominium as a joint Anglo-French effort has reached an advanced stage. Plans to set up a similar station at Tarawa in the Gilbert Islands, and to add radiosonde equipment to the existing station at Funafuti in the Ellice Islands, are also in hand.

Offers of equipment made through WMO's Voluntary Assistance Programme (VAP) to help some other Members implement important parts of the WWW Plan, and accepted by them in principle, were each discussed in detail with the recipients in order to ensure that effective and satisfactory results are obtained from the equipment. A number of training fellowships were also offered through VAP and accepted. These fellowships support students through appropriate university courses, as a means of training meteorologists for employment by developing countries.

The main internal task was the planning with the Ministry of Public Building and Works, of a new wing for the Headquarters building. This wing is to house the new very large computer and those branches whose work is most closely related to it operationally, i.e. Central Forecasting and Telecommunications. The Planning Branch acted as co-ordinator for the three branches concerned and point of contact with MPBW. The Branch was also involved in discussions of several other projects for modifying or adding to Office accommodation in Bracknell.

The five-year plan for the Office was up-dated early in the year.

P. J. MEADE
Director of Services

SUMMARY OF THE WEATHER OF 1969

Noteworthy features of the weather during 1969 included a very snowy February and a record gust of 118 knots at Kirkwall (Orkney); the dry winter and spring in north-west Scotland contrasting sharply with the waterlogged state of the ground in eastern England; a memorably sunny Easter in April followed by a wet, thundery May; some long dry spells in summer and autumn but also some very heavy falls of rain; an Indian summer over much of the country in October, the month being very warm and exceptionally dry in many areas; snow in many areas earlier than usual in November.

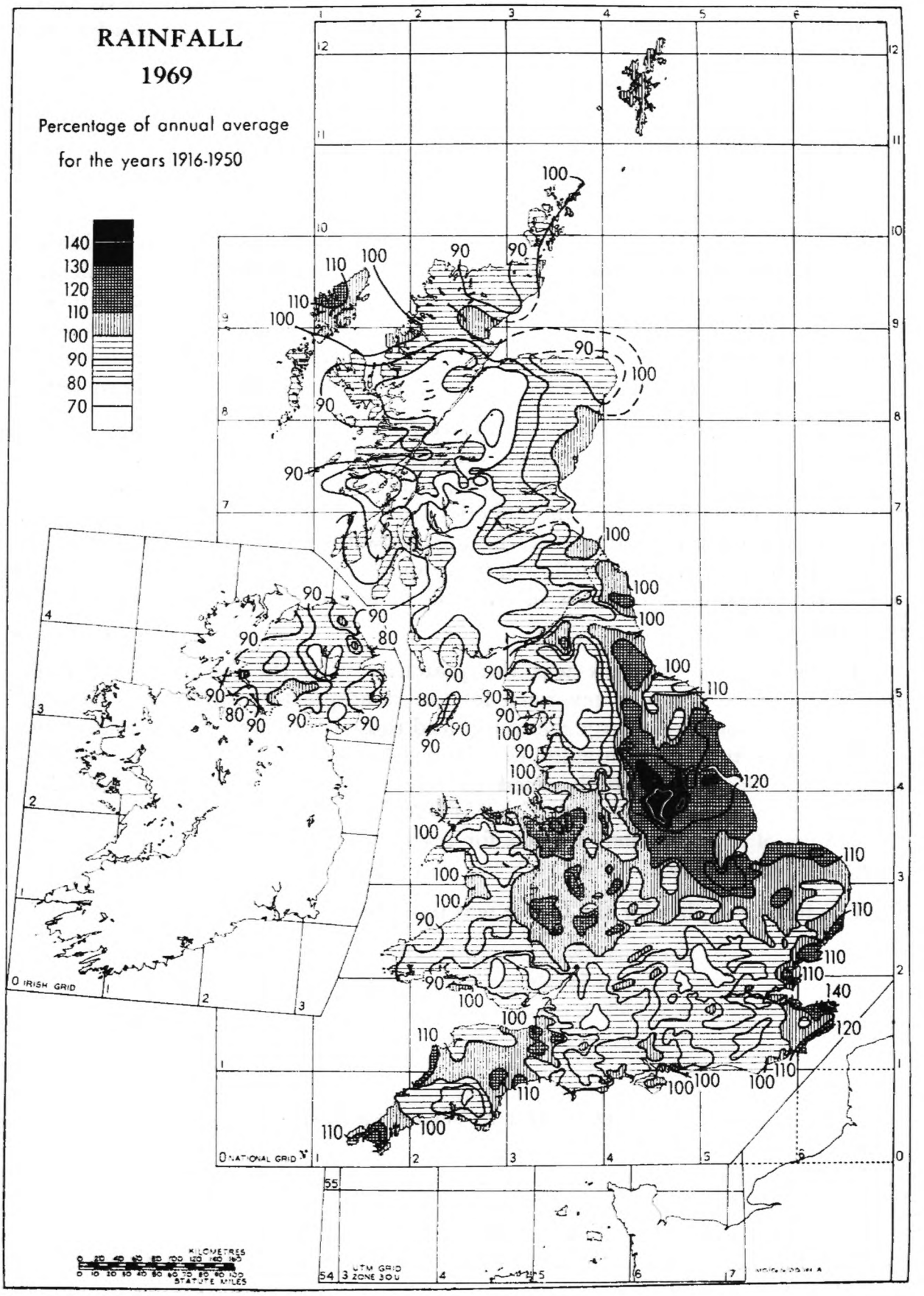


FIGURE 2—RAINFALL 1969

January. The month was, in general, dull and mild especially during the fourth week. For a few days around the 22nd, mean daily temperature was about 7 degC above average in places in the south. The temperature reached 15°C at Camden Square (London) on the 22nd; this is the highest January temperature recorded there during this century. The weather was mostly unsettled with some heavy rain at times and local flooding occurred. At Bryn Gwynant (Caernarvonshire), 124 mm of rain were recorded in the 24 hours ending 0900 GMT on the 21st and during the same period heavy falls occurred in many parts of Wales, the Midlands and north-west England. Although the frequency of gale force winds was rather below average some notable gusts occurred; one of 90 knots was reported at Earl's Hill, near Stirling, on the 30th and a gust of 79 knots was recorded in the Isles of Scilly on the 17th. It was the dullest January for 19 years at Tiree, in the Western Isles.

February. Predominantly north or east winds led to a very cold and snowy month with blizzards in many places. On the morning of the 7th a gust of 118 knots was recorded at Kirkwall (Orkney) which was accompanied by a temperature of −4°C. This is the highest confirmed gust at a low-level station in the United Kingdom. The frequency of snowfall was much greater than normal and strong winds often resulted in severe drifting. On the 7th, 10–15 cm of snow fell over wide areas from Northern Ireland and southern Scotland southwards. Over 30 cm of snow were lying in the Deal area of Kent by the 8th and deep snowdrifts had built up. Falls of over 25 cm occurred in Northern Ireland on the 9th and 10th in heavy snow showers. On the 13th and 14th heavy snow fell in Scotland, Wales and northern England; more than 15 cm were lying in places on the 14th. By the 15th villages in the North Riding of Yorkshire were isolated. On the 19th, 10–15 cm of snow fell in many parts of Wales and southern England and deep drifts built up on high ground. On the same day an easterly gale caused damage to property in the west country and parts of the south Devon coast were flooded when sea-defences were breached.

March. It was very dry in northern districts, notably in western Scotland where Tiree had only 5 mm of rain during the whole month. It was the driest March at Stornoway (Hebrides) since records began in 1871. In contrast, the rainfall total for the period 11th to 13th in south and east England was nearly equal to the average value for March. Snow was mostly confined to northern areas where, except on high ground, it was generally slight. However, heavy falls occurred around the 13th and snowdrifts isolated villages in northern England and southern Scotland; blizzards were reported in places from North Wales to eastern Scotland. Except in some western areas it was a very dull month; it was the dullest March at Kew (south-west London) since 1916. It was also, in general, the coldest March since 1962 with a high frequency of east or south-east winds which made eastern coastal waters very rough at times. From the 16th to 18th freezing rain or drizzle caused widespread glazed frost in the Midlands and the north of England. Accumulations of ice were heavy at heights above about 150 m (500 feet); TV masts were damaged and telephone and power cables were brought down.

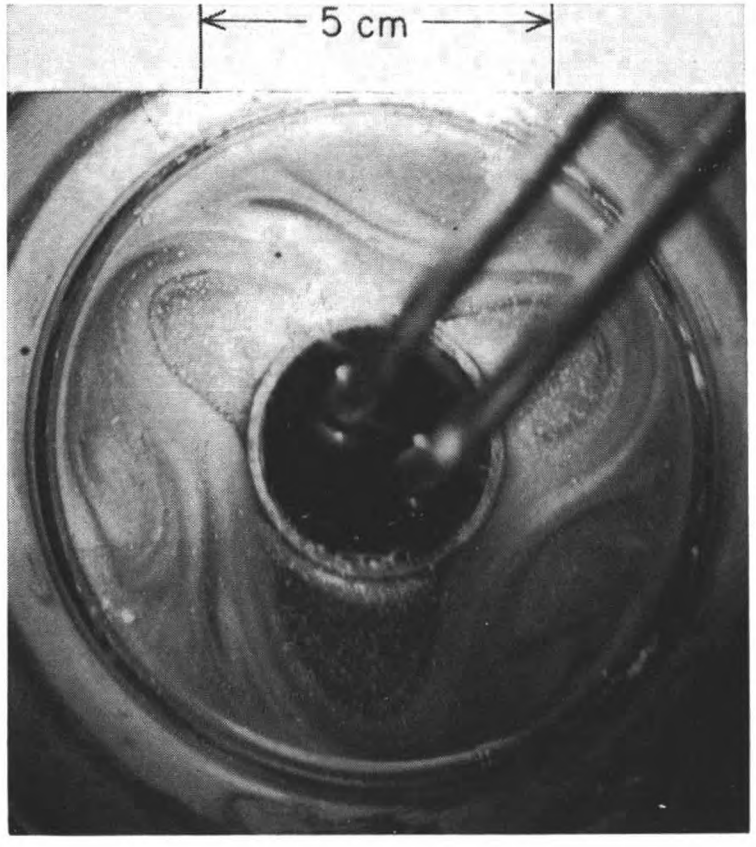
April. Although high pressure dominated the weather during the first week and for a few days around the 18th, April contained some stormy periods

especially from the 21st to 28th when rain was often thundery. The 12th was very windy everywhere and gusts in excess of 70 knots were reported from places as far apart as Stirlingshire and Somerset. It was a very sunny month except in east Scotland and on coasts in eastern England. Oxford had its sunniest April since 1914 and many places recorded their largest April sunshine total for over 15 years. The Easter period (4th–7th) was reported to have been the sunniest Easter in Manchester since at least 1902. However, despite the sunshine it was rather cold. Snow was infrequent but wintry showers occurred widely in Scotland during the second week. April was the sixth consecutive month with rainfall below average at many places in west Scotland but more than twice the average rainfall occurred in north Lincolnshire.

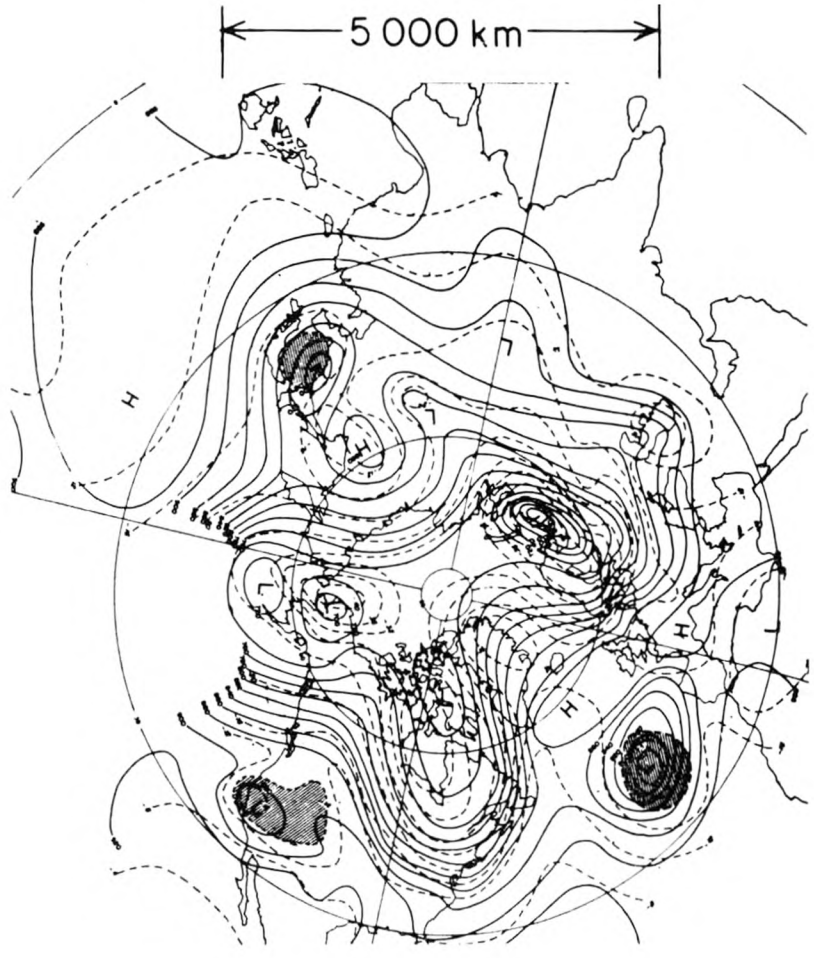
May. The weather during May was very changeable and periods of thundery rain alternated with brighter, though showery, interludes. The rain was often heavy and thunderstorms occurred frequently, particularly in England. Near Birmingham thunderstorms were reported on 11 days which is about 5 times the average for May in this area; lightning strikes causing damage occurred in many places and at least one person was killed. Most places had above average rainfall; it was the wettest May on record at Montrose (Angus) and Bidston (Cheshire) where observations commenced in 1866 and 1867 respectively. In complete contrast it was the seventh consecutive month with below average rainfall in the Fort William (Inverness-shire) area. The 24th and 25th were particularly wet in the west Midlands and Wales; many places in these areas had 'daily' falls of over 50 mm and at Knotty Ash, Liverpool, 27 mm of rain fell in about 35 minutes on the 24th. The month was also very dull and at Eskdalemuir and Dumfries it was the dullest May since records commenced in 1910.

June. The weather was unsettled at first in the west and north but it became fine and dry nearly everywhere by the end of the first week and most places had a dry spell from the 5th to 13th. However, from mid-month it was changeable although dry weather returned to the south during the last week. Rainfall was thundery at times and a number of exceptional falls occurred. On the 14th, at Worsborough Dale, near Barnsley (West Riding of Yorkshire), 59 mm of rain fell in 45 minutes. This rainfall is classified as 'very rare' and, statistically, may be expected to occur at a particular place on only 1 day in about 160 years. On the next day at Dudley (Worcestershire), 35 mm fell in 18 minutes; this is a 'remarkable' fall of rain which may be expected, on average, to occur at a particular place on only 1 day in about 40 years. Another 'remarkable' fall occurred at Leigh Holt (Somerset) on the 18th where about 59 mm of rain were measured in 3 hours. During the month lightning strikes killed one person and damaged property in many places. Monthly mean temperature was about average while sunshine was above normal nearly everywhere and was particularly abundant during the second week. It was the sunniest June in central London for at least 40 years.

July. The month was sunny with a warm, dry spell in southern districts from the 9th to the 27th. Although further north it was mostly changeable, some areas had a very dry month. At Dumfries it was the driest July since 1913 and at Douglas (Isle of Man) since 1934. Rainfall in parts of Northern Ireland was as low as 15 per cent of average. Some notable falls of rain causing local flooding



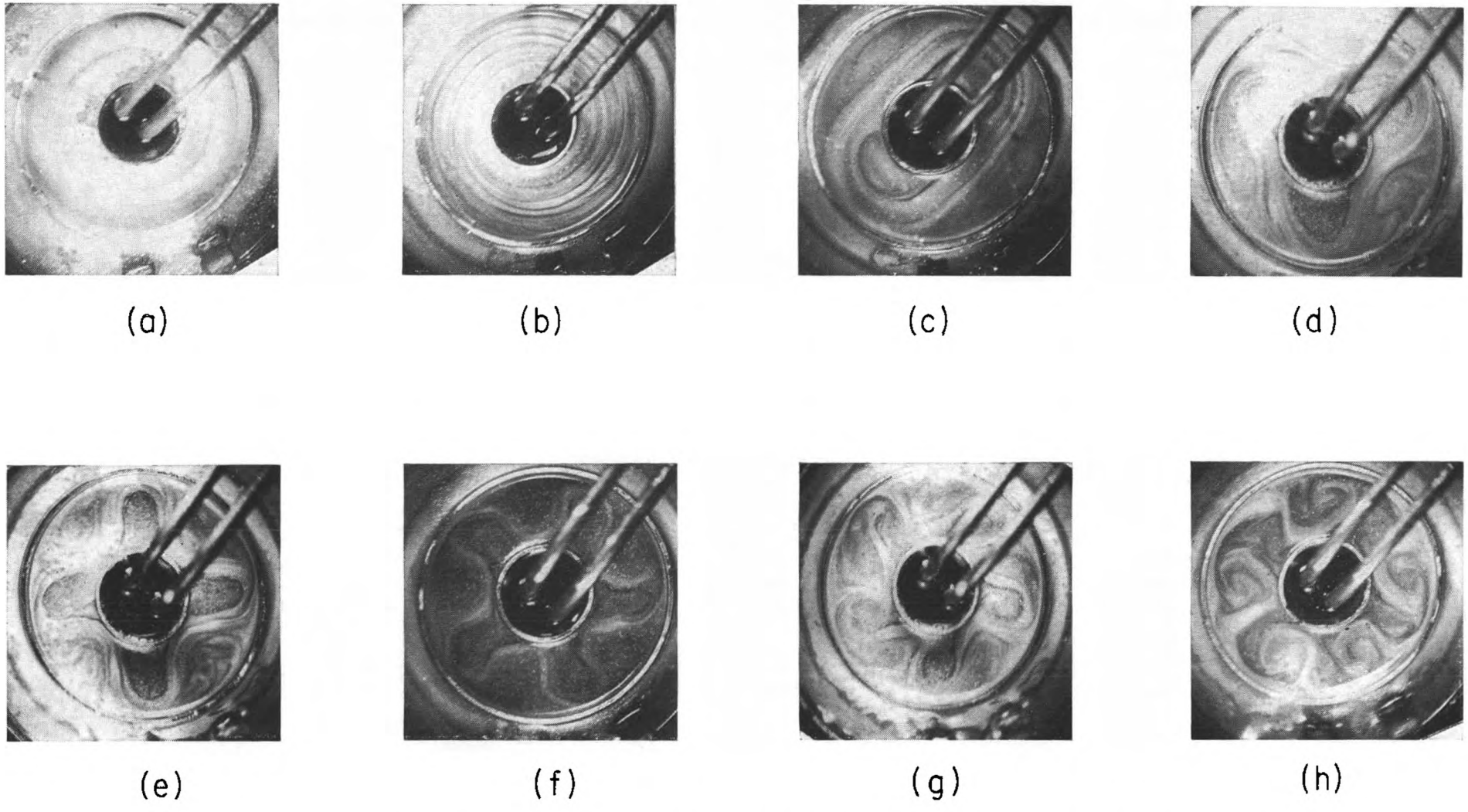
(*a*) Top-surface flow pattern in the steady-wave régime of thermal convection in a rotating annulus of water. Bounding cylinders maintained at temperature T_b and T_a ($T_b > T_a$). Aluminium powder in suspension used as indicator.



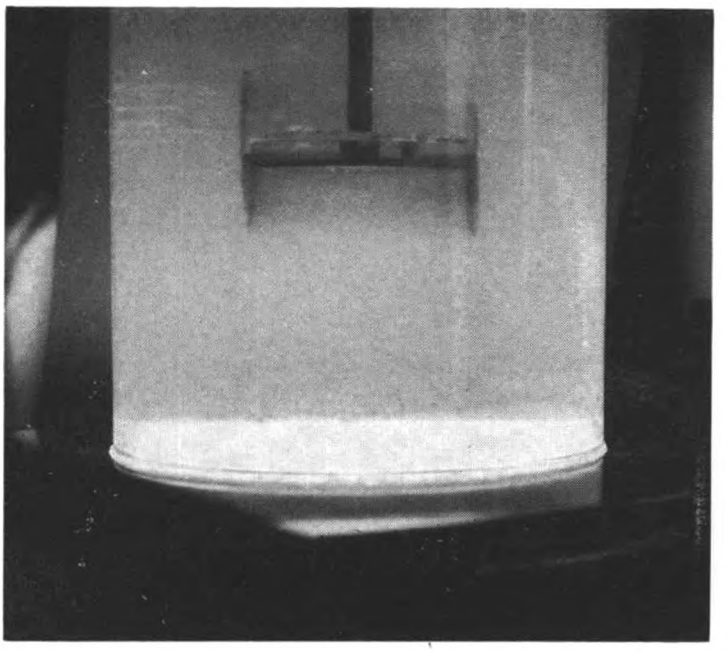
(*b*) Contours (———) and isotherms (- - - - -) at the 500-mb level on 12 October 1945 at 04 GMT. Contour lines drawn for intervals of 200 ft.

COMPARISON OF FLOW IN A ROTATING ANNULUS WITH CIRCUMPOLAR CURRENT IN THE ATMOSPHERE

PLATE I

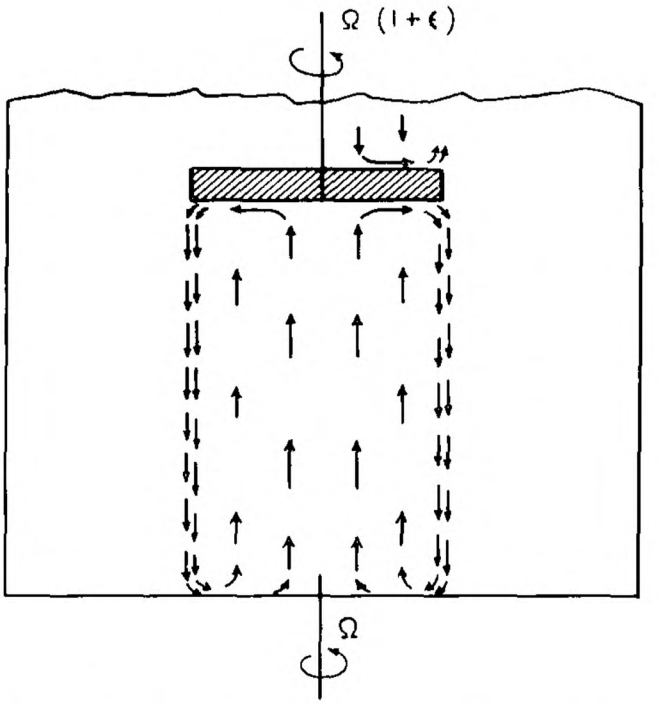


THERMAL CONVECTION IN A ROTATING ANNULUS OF LIQUID, ILLUSTRATING THE DEPENDENCE OF UPPER-SURFACE FLOW PATTERN ON THE RATE OF ROTATION OF THE APPARATUS



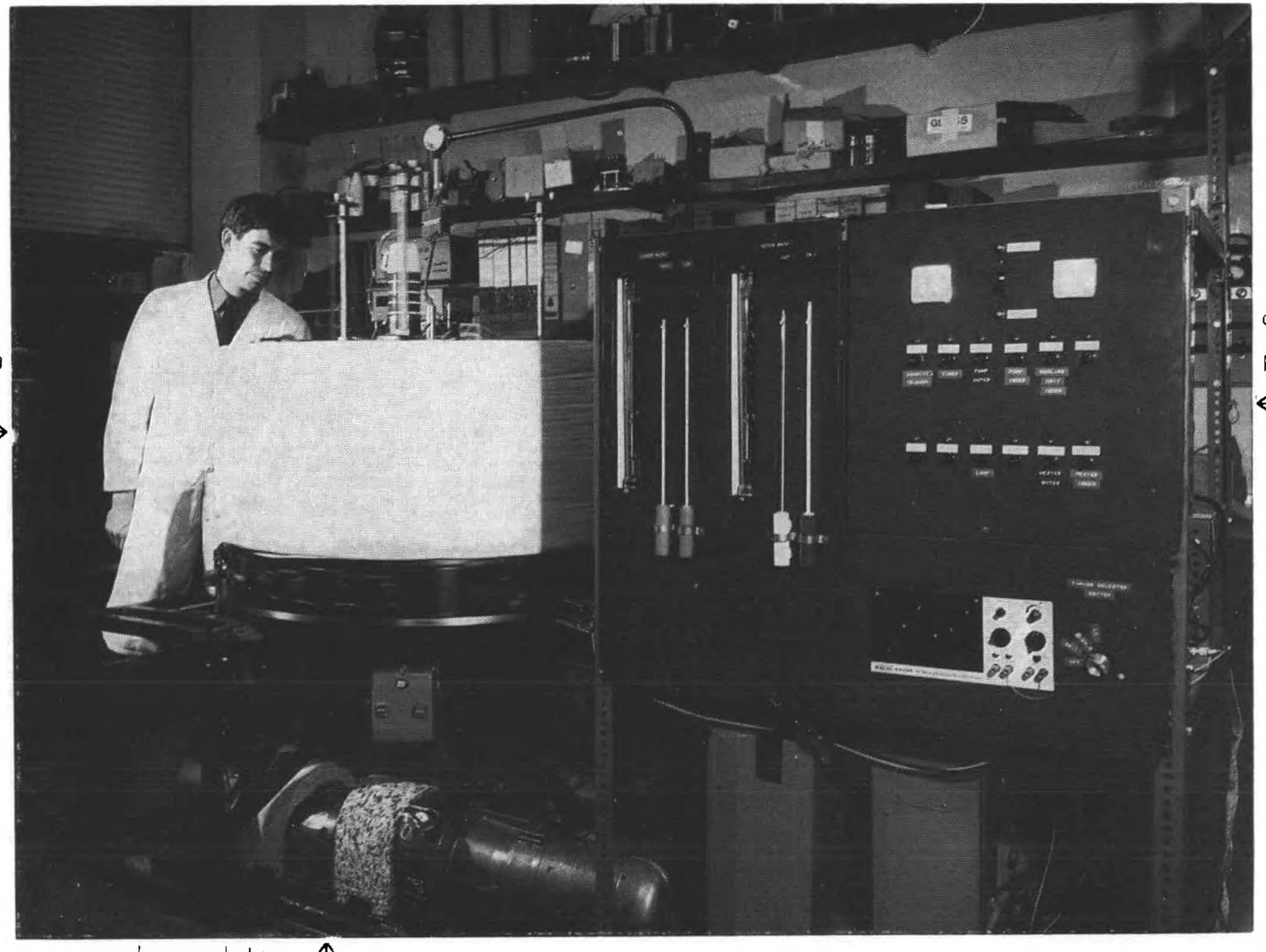
DETACHED SHEAR LAYER DUE TO THE SLOW ROTATION OF A DISC RELATIVE TO A RAPIDLY ROTATING FLUID

The photograph was taken several minutes after the commencement of the release of dye from the rim of the disc. The dye has been carried downward (and upward) but has not moved horizontally beyond the rim of the disc. The detached shear layer within the fluid is marked by a strong concentration of dye.



SIMPLIFIED DIAGRAM OF THE AXISYMMETRIC FLOW RÉGIME

An axisymmetric flow is generated when a disc rotates slowly relative to a rapidly rotating fluid. A cylindrical region of high shear is developed within the fluid, i.e. detached from any solid boundary. The diagram shows a section through the flow in a tank of water rotating at angular velocity Ω, while a disc is rotating at angular velocity $\Omega\,(1+\varepsilon)$ where $\varepsilon \ll 1$. The axes of rotation of the disc and tank coincide. The flow above the disc is not shown in full but is identical to that below it.



LARGE ROTATING ANNULUS AND ANCILLARY EQUIPMENT

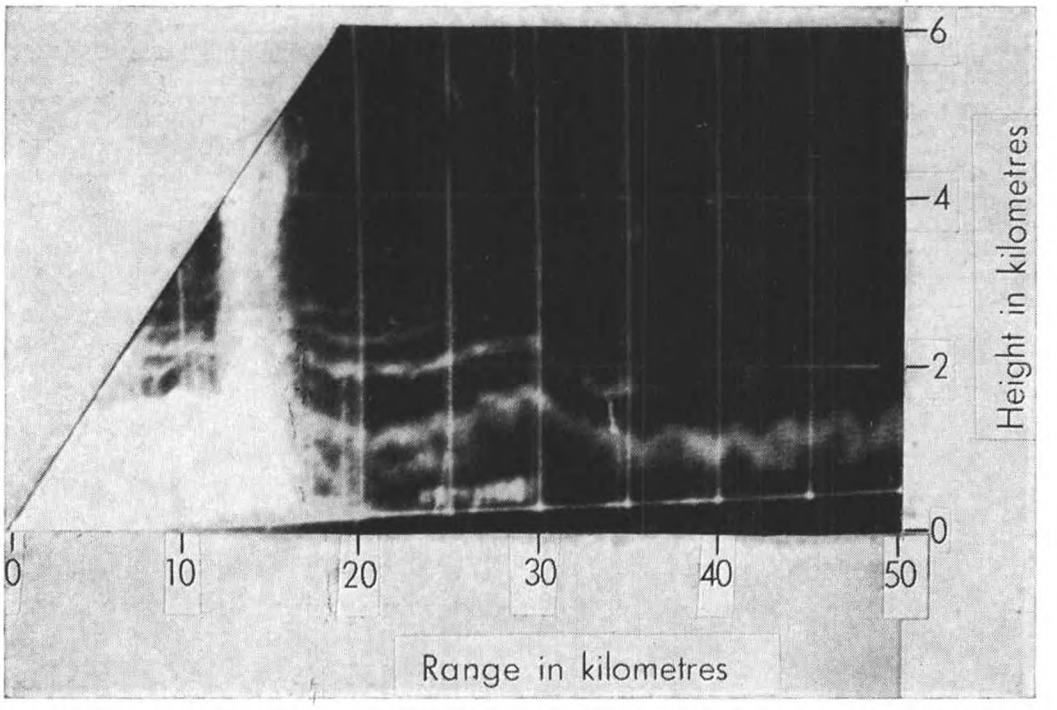
PLATE V

LABORATORY STUDIES OF EIGENOSCILLATIONS OF A ROTATING FLUID

PLATE VI

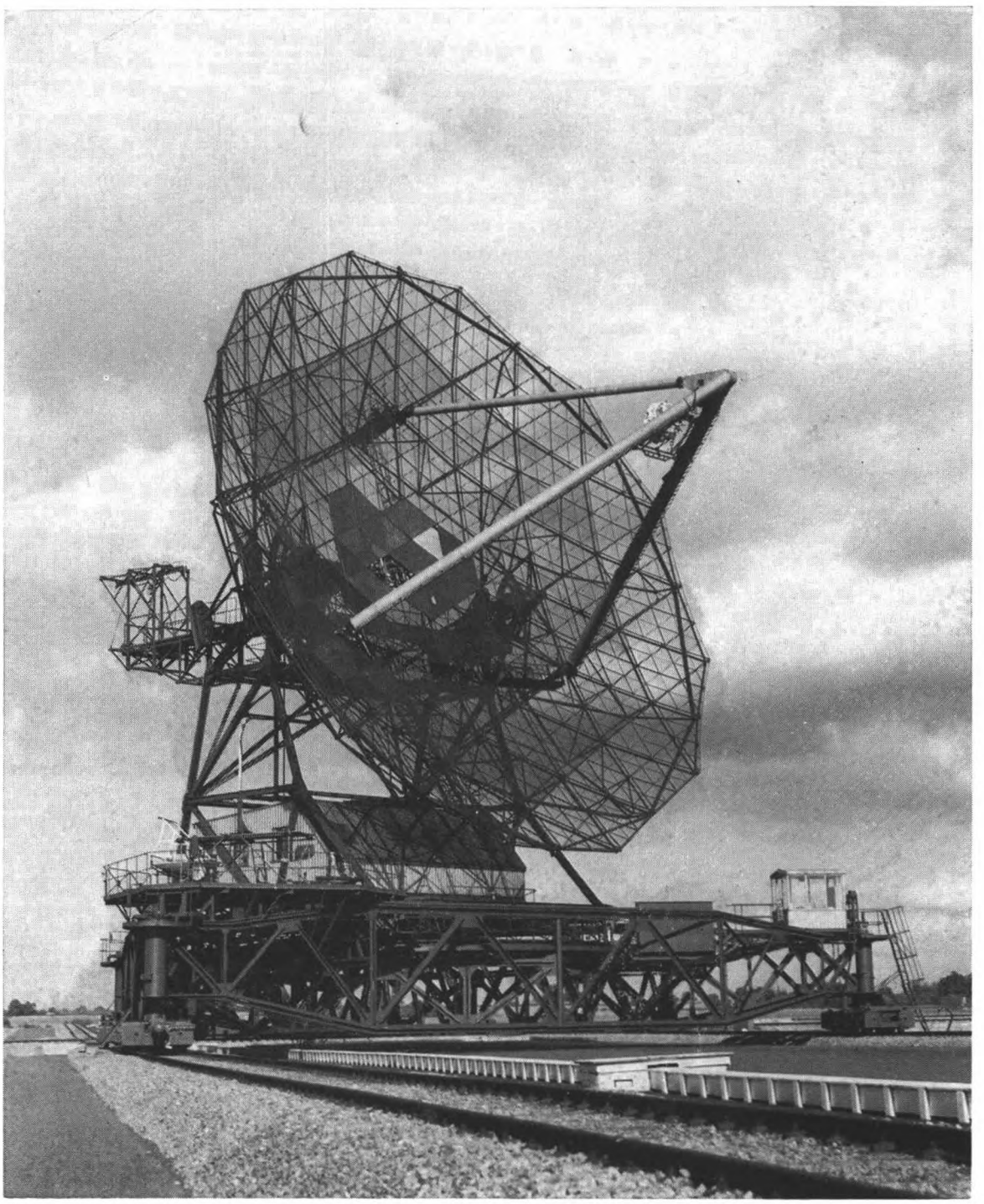
THE MOBILE DOPPLER RADAR OF THE
METEOROLOGICAL RESEARCH UNIT AT RRE MALVERN

This radar measures the velocity of raindrops and so can be used to study the development of the size spectrum of raindrops in the atmosphere and, more important, can be used to gain unique information on the airflow in and below precipitating clouds.



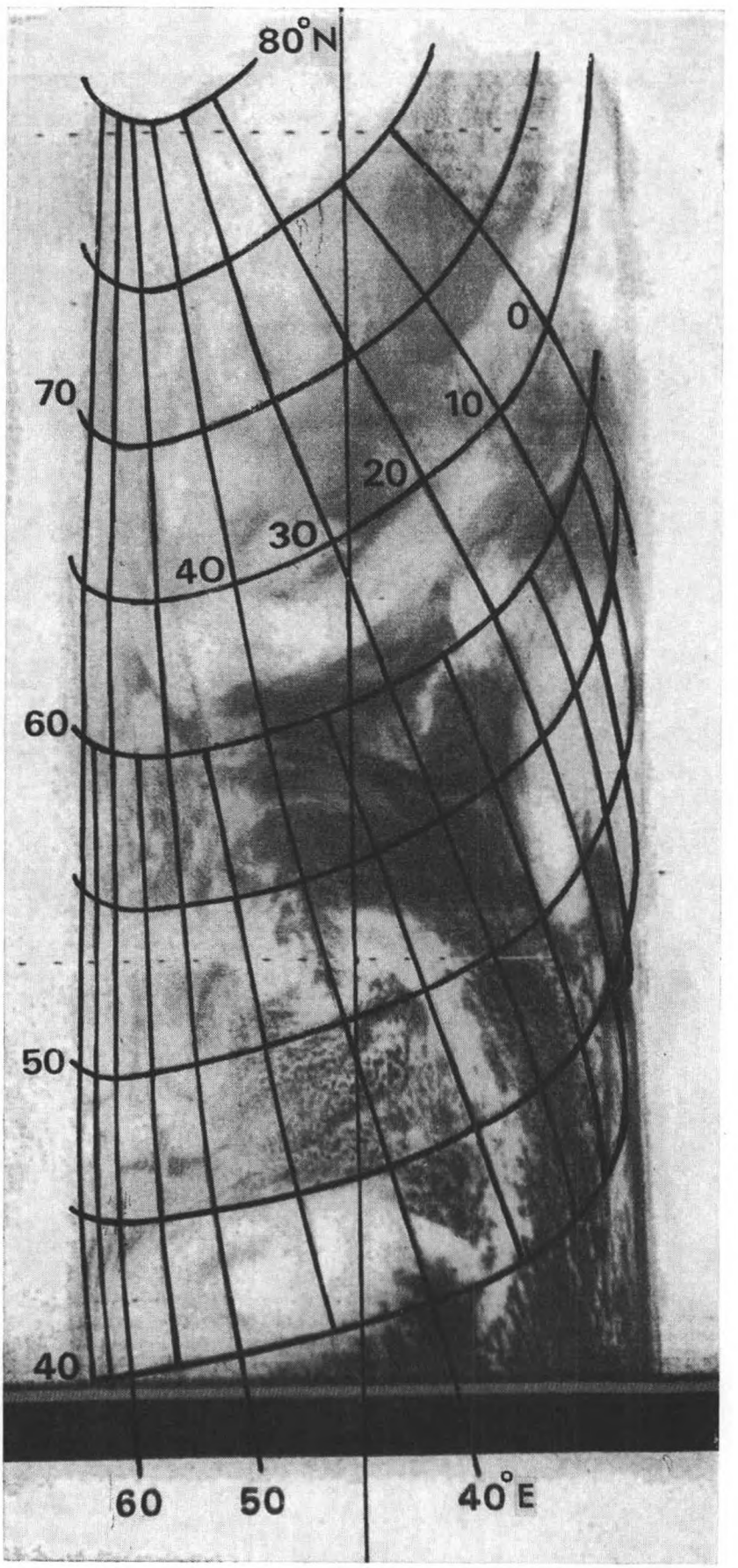
RHI DISPLAY LOOKING TOWARDS 260° FROM RRE DEFFORD

Clear-air layers are to be seen up to a height of 3 km and out to a range of more than 50 km. The solid echoes out to 17 km are due to side-lobe returns from the ground. In the future they will be considerably decreased by using MTI techniques.



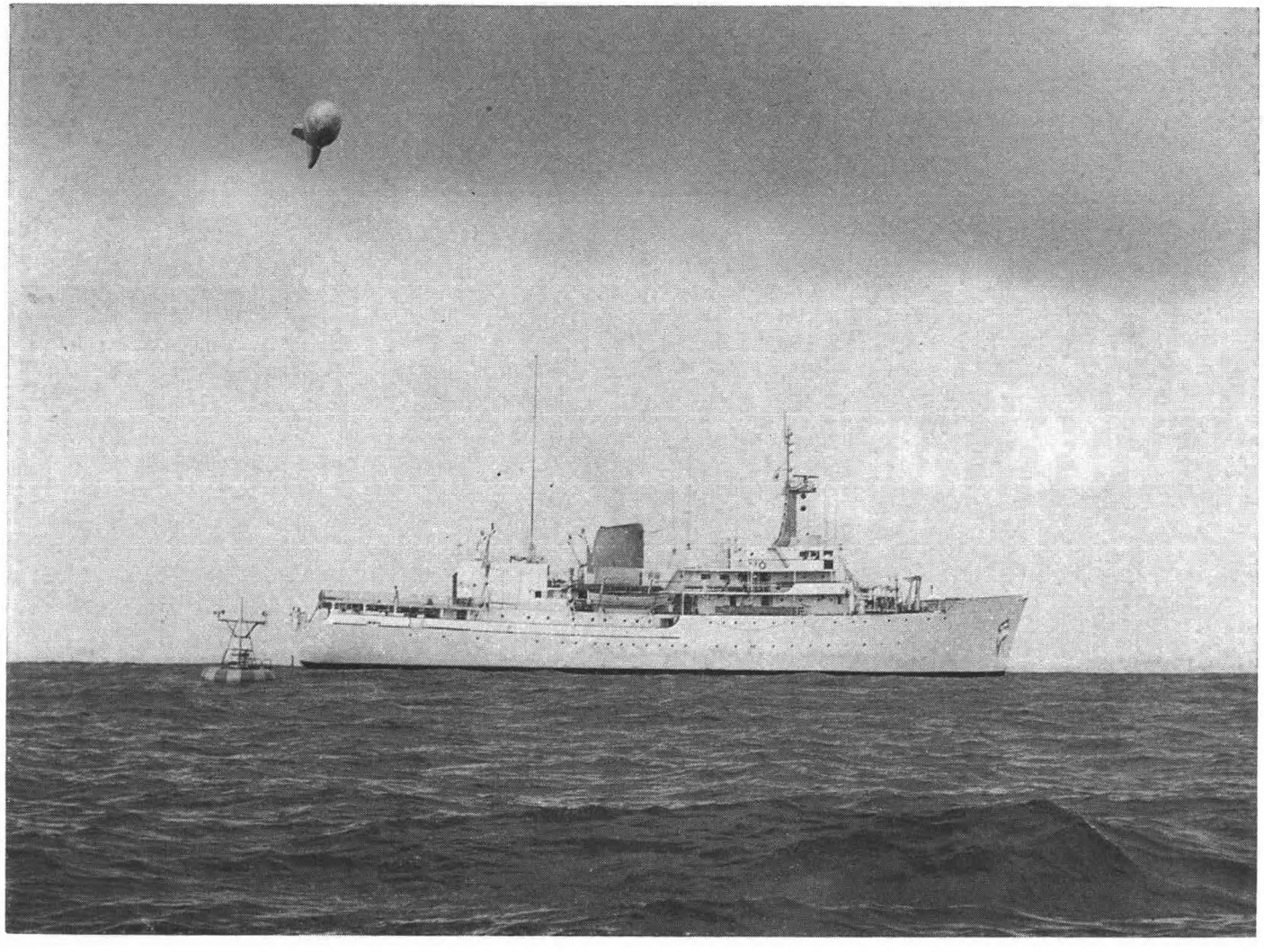
TWENTY-FIVE-METRE STEERABLE DISH AT RRE DEFFORD

PLATE VIII



INFRA-RED PICTURE OF THE EASTERN ATLANTIC AREA RECEIVED A' BRACKNELL FROM U.S. WEATHER SATELLITE NIMBUS III

The white areas, in general, display the main cloud systems.



Photograph by courtesy of the Hydrographer of the Navy

AIR-SEA INTERACTION

Measuring turbulence and turbulent transfer over the sea during the Atlantic Trade Wind Expedition (ANTEX) in February 1969. The tethered balloon supports instruments measuring turbulent fluctuations of wind and temperature: the data are passed to the ship (H.M.S. *Hydra*) via a radio link. The buoy records air and sea temperatures and wind speed on a magnetic-tape unit mounted within its superstructure.

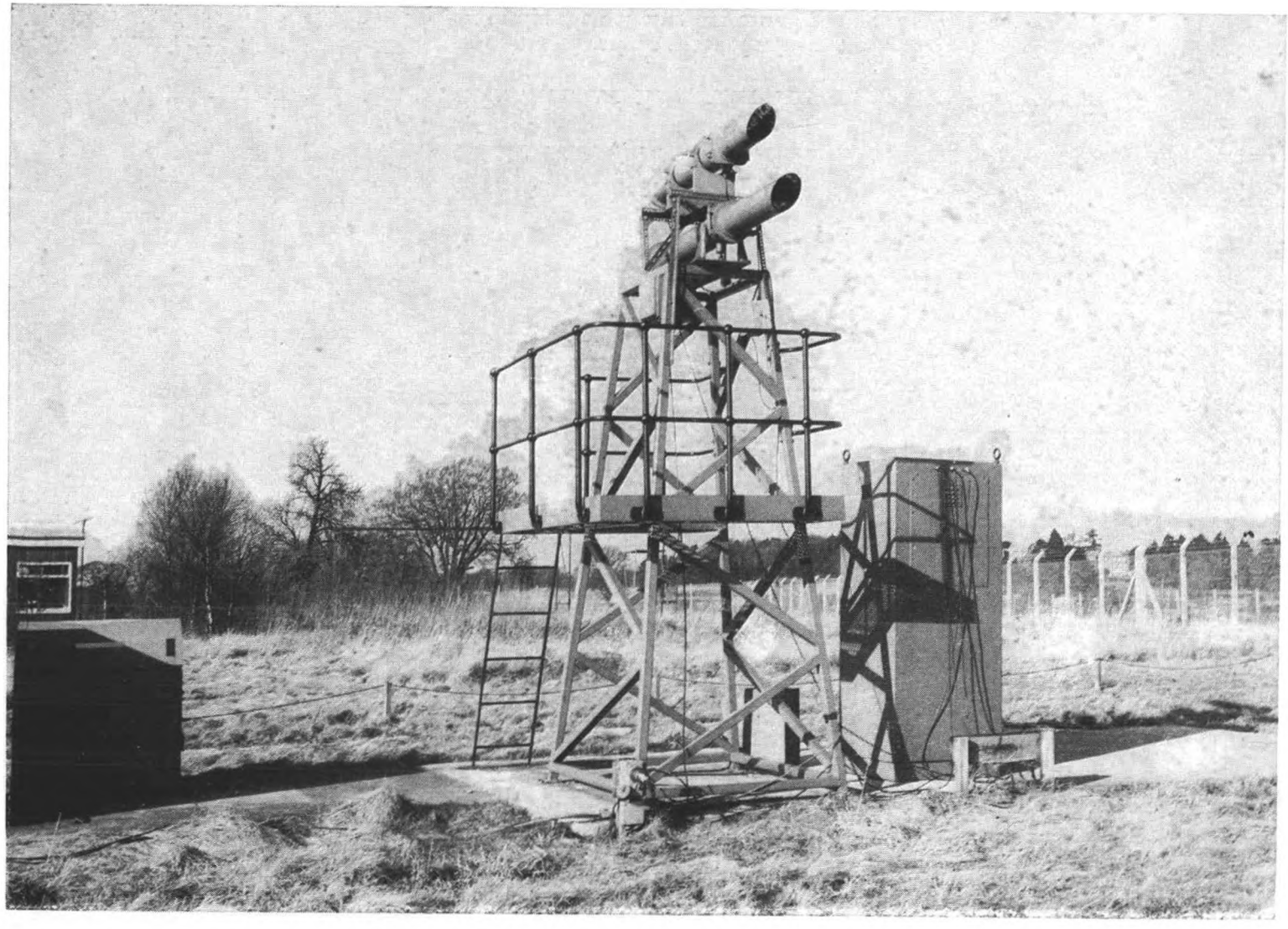
PLATE IX

PART OF THE NEW INSTRUMENT TEST ROOM IN THE SIMPSON BUILDING, WESTERN ROAD, BRACKNELL

A wide range of calibration and test facilities is provided for checking the performance of meteorological equipment.

PART OF THE EXPERIMENTAL SITE AT EASTHAMPSTEAD PARK NEAR BRACKNELL

The area in the foreground is being used for comparison of various types of rain-gauge, while the masts in the background are part of a communications link with Malta, provided for the location of thunderstorms by radio direction-finding.



TRANSMISSOMETER RECEIVERS FOR VISIBILITY MEASUREMENT AND REMOTE RECORDING, SET UP FOR COMPARATIVE TRIALS AT THE EXPERIMENTAL SITE AT EASTHAMPSTEAD PARK

occurred during the month. On the 6th, a depression moving eastward over northern France gave heavy rain in southern and eastern England. A 'remarkable' fall of rain occurred at Rainham (Essex) where 127 mm were recorded in the 24 hours ending 0900 GMT on the 7th. Between the 12th and 22nd 'daily' falls of over 50 mm occurred at times in places in west Scotland. The dry spell in the south ended on the 28th and the 24-hour period ending 0900 GMT on the 29th was the wettest 'day' in the Plymouth area since before 1876; also a number of 'very rare' falls of rain occurred in south-west England. These included 145 mm at Ellbridge, near Plymouth, and over 144 mm at North Hessary Tor, on Dartmoor. 'Daily' falls in excess of 100 mm were recorded at places in Somerset, Devon and Cornwall.

August. The first three weeks were rather warm and temperatures exceeded 30°C at times in parts of eastern and southern England but the last 10 days were cooler. Although sunshine was near the normal in many places it was the dullest August at Mildenhall (Suffolk) since records began in 1936 and the sunniest in the Glasgow area since 1947. Northern Ireland had, in general, its driest August for 10 years. Thundery rain occurred in many areas during the month. From the 1st to the 3rd a complex area of low pressure covered the British Isles and a small depression moved from northern France across all districts. Rain was exceptionally heavy in south-east England on the 2nd/3rd. At Hampton, in south-west London, over 96 mm of rain (nearly twice the monthly average) fell in 10 hours during which 31 mm occurred in 30 minutes. At Southam (Warwickshire) a 'daily' fall of 127 mm was recorded on the 2nd. These falls are classified as 'remarkable' and another of 46 mm in 1 hour occurred at Manston (Kent) on the 15th where the average rainfall for the month is 50 mm. During a heavy thunderstorm on the 16th, over 77 mm of rain fell in 2 hours at Coulter Reservoir, near Symington (Lanarkshire)—this is a 'very rare' rainfall. A 'daily' fall of nearly 103 mm occurred at Ashycroft (Cumberland), near the Scottish border, on the 20th, most of which was estimated to have fallen in 6 hours during a thunderstorm. This is another 'very rare' rainfall and the associated flood-water caused damage to roads in the area.

September. It was very dry in eastern England, rivalling the dry September of 1959. Many places in East Anglia and the London area recorded less than 5 mm of rain and the monthly total of 0·3 mm (measured as 0·01 in) at Mepal (Cambridgeshire) fell on 1 day—the 16th. In many areas it was the driest September for 10 years and in Northern Ireland as a whole since 1933. Water rationing was instituted in Glasgow. In contrast it was the wettest September at Lerwick (Shetland) and Stornoway (Hebrides) since 1917 and 1950 respectively. The month contained some very stormy periods in northern districts and there were widespread gales at times. These occurred notably on the 21st and 28th when gusts in excess of 80 knots were reported widely in Scotland and as far south as Yorkshire. At Cairngorm, 1090 m (Inverness-shire), gusts of 104 knots and 106 knots were recorded on the 21st and 28th respectively. Gusts over 90 knots were reported at Earl's Hill on the same two days.

October. Although it was changeable in north Scotland, dry weather continued in most other districts. It is estimated that the general areal rainfall over England and Wales has not been lower in October since 1784 although it was equalled in this month in 1809 and 1947. It was the driest October at Oxford (Radcliffe Observatory) and Durham since records commenced in 1815 and

1879 respectively and at least one station (near Bedford) had no measurable rainfall throughout the month. Restrictions on the use of water were extended to many urban areas. Southerly winds at times led to an unusually warm, often foggy month, with mean temperature over 3 degC above average in a number of places. It was the mildest October at Durham since records commenced in 1847 and the mildest at Kew since continuous records began about 1868. On the 9th or 10th many places had their warmest October day since 1959 and 26·5°C was recorded at East Dereham (Norfolk) on the 9th. There were a number of stormy periods in the month; a gust of 85 knots was recorded at Cairngorm on the 7th and gusts over 60 knots occurred widely in western Scotland and northern England on the 24th.

November. The mild weather continued during the first three days of the month and some places had their warmest November day on record on the 2nd or 3rd. However, it soon became colder and frost was frequent in Scotland where the monthly mean temperature was more than 3 degC below average in some areas and Lerwick had its coldest November since records began in 1926. Snow occurred frequently in the north and there were also some notable falls further south; during a snowy period around mid-month, 20 cm of snow accumulated in 4 hours at Ashover, height 186 m (Derbyshire), on the 16th. Sleet was reported in Devon as early as the 8th and occurred in Jersey on the 17th, while snow settled on Dartmoor on the 15th. Some heavy rain fell in most districts and it was the wettest November at Bidston since records commenced in 1867. Exceptionally heavy rain occurred in Northern Ireland on the 21st and 22nd associated with a slow-moving depression. During the 24-hour period ending 0900 GMT on the 22nd, nearly 138 mm of rain were recorded at Ballybraddin Forest (Co. Antrim) and falls in excess of 100 mm occurred in the same area. These falls are classified as 'remarkable'. In the same period, Armagh Observatory had its greatest 'daily' fall of rain since records began in 1841 and Omagh (Co. Tyrone) was isolated by flood-water. The rather stormy month resulted in an exceptionally fog-free November. Gales were twice as frequent as usual on exposed coasts and a gust of 83 knots was reported at Brixham (Devon) on the 9th. Nevertheless, it was sunnier than average in most areas.

December. North or east winds, although alternating with more changeable spells of weather, resulted in a colder than average December especially in the south. Snow occurred during the first week in Scotland and at times in east coast areas of England. Easterly winds brought snow to many areas from the 17th to 19th and blizzards occurred in south-west Scotland, north-west England and in Wales on the 19th. Slight snow fell in southern districts during the last few days. It was a rather wet month in parts of eastern England. During a stormy period around mid-month, exceptionally heavy rain caused flooding in northern England and North Wales. On the 14th, a rainfall of over 90 mm in 24 hours was reported in north-west England and gales were severe in the south-west where a gust of 71 knots occurred at Brixham. There were some foggy periods and it was a very dull month in eastern England. Fog was widespread at times during the second week; it was locally dense and sometimes persisted all day in industrial areas. Freezing fog developed in parts of Scotland and northern England on Christmas morning. The year ended with strong and very cold easterly winds in England and Wales accompanied by occasional slight snow, while in Scotland and Northern Ireland it was somewhat less cold.

STATISTICS OF THE SERVICES DIRECTORATE

The quantitative analyses in this section are intended to provide an indication of the distribution of work within the Directorate of Services and of the extent of the services provided.

TABLE I—NUMBERS OF OFFICES OF VARIOUS TYPES STAFFED BY METEOROLOGICAL OFFICE STAFF AND OPERATING ON 31 DECEMBER 1969

	Within U.K.	Overseas
Principal Forecasting Offices associated with the RAF	1	—
Main Meteorological Offices associated with the RAF	8	6
Subsidiary offices associated with the RAF	40	11
Observing offices associated with the RAF	8	4
Principal Forecasting Offices associated with civil aviation	1	—
Main Meteorological Offices associated with civil aviation	3	—
Subsidiary offices associated with civil aviation	11	—
Observing offices associated with civil aviation	6	—
Upper air observing offices	8	7
Public service offices	6	—
CRDF offices	5	3
Port Meteorological Offices	5	—
Offices associated with the National Agricultural Advisory Service	3	—
Other offices	27*	5

* Eight of these stations are administered by D.R.Met.O.

Notes

A Principal Forecasting Office meets the needs of aircraft flying over very long distances and operates throughout the 24 hours.

A Main Meteorological Office operates throughout the 24 hours for the benefit of aviation and normally supervises the work of subsidiary offices.

A subsidiary office is open for that part of the day necessary to meet aviation requirements.

At an observing office no forecaster is available.

An upper air observing office may be located with an office of another type if this is convenient.

Public service offices are located in certain large cities.

CRDF offices form the network for thunderstorm location.

Port Meteorological Offices are maintained at the bigger ports.

TABLE II—OCEAN WEATHER SHIPS

To meet its obligation under the ICAO North Atlantic Ocean Station Agreement the United Kingdom operates four Ocean Weather Ships which work in rotation with two ships from France, two ships from the Netherlands and two ships jointly operated by Norway and Sweden. The British ships serve at four of the five ocean weather stations in the eastern North Atlantic; each vessel makes, on average, eight voyages a year and spends an average of 24 days on station during each voyage. Some statistics for 1969 for the British Ocean Weather Ships are shown below.

Total number of days on station	727·2
Total number of days on passage	168·2

	Station A	Station I	Station J	Station K
	average number per voyage			
Aircraft contacted	257	421	887	295
Number of aircraft given one or more radar fixes	171	309	600	197
Weather messages to aircraft	373	447	551	218

TABLE III—MERCHANT NAVY SHIPS

A total of about 5800 ships of the merchant navies of the world make and transmit meteorological reports to the appropriate meteorological centres ashore under arrangements co-ordinated by the World Meteorological Organization. Most of them, including British ships, do this on a voluntary basis. Ships which report in full at four specified times daily are known as 'selected ships'; those which report at the same times daily, but in a less complete form, are known as 'supplementary ships'. A number of coasting vessels, lightships, distant-water trawlers and 'auxiliary ships' also make and transmit meteorological observations.

On 31 December 1969 the numbers of British ships reporting were:

Selected ships	499
Supplementary ships	59
	including 20 trawlers
Coasting vessels	77
Lightships	15
Trawlers	33
Auxiliary ships	52
Total	735

The British Voluntary Observing Fleet includes ships of over 100 shipping companies, and the numbers on the various routes are as follows:

U.K. to Australasia	91
U.K. to Far East	98
U.K. to Persian Gulf	37
U.K. to South Africa	31
U.K. to West Indies	33
U.K. to Atlantic coast of North America	92
U.K. to Pacific coast of North America	13
U.K. to South America	17
U.K. to European ports	35
U.K. to Falkland Islands and Antarctica	1
U.K. to distant-water fishing grounds	20
World-wide tramping	90

During two typical days, one in June, the other in December, the numbers of reports from ships received in the Central Forecasting Office were as follows:

	Reports *June*	Reports *December*
Direct reception from:		
British ships in eastern North Atlantic	90	93
Foreign ships in eastern North Atlantic	8	58
British trawlers in North Sea	13	14
British merchant ships in North Sea	28	12
Total	139	177
Reception via other European countries:		
Ships in eastern North Atlantic	327	250
Ships in Mediterranean	77	50
Ships in North Sea	91	102
Ships off north Russia	37	36
Ships in other European waters	16	15
Ships in Pacific	18	35
Total	566	488
Reception via U.S.A. and Canada:		
Ships in North Atlantic	464	431
Ships in North Pacific	641	604
Ships in other waters	15	22
Total	1120	1057

TABLE IV—CLASSIFICATION OF STATIONS RENDERING CLIMATOLOGICAL RETURNS

A large amount of meteorological data is obtained for climatological purposes from stations which are not part of the Meteorological Office organization. The following table shows how the sources of climatological information in the United Kingdom (including Meteorological Office stations) were distributed on 31 December 1969.

	Stations					Autographic Records		
	Observatories	*Synoptic*	*Agrometeorological*	*Climatological*	*Rainfall**	*Sunshine*	*Rainfall*	*Wind*
Scotland, north	1	10	0	27	339	27	8	12
Scotland, east	0	10	9	68	573	49	17	11
Scotland, west	1	13	2	54	521	34	17	11
England, north-east	0	10	4	25	470	28	17	10
England, east	0	11	14	17	583	31	23	13
England, Midlands	0	13	16	51	1350	60	31	13
England, south-east (including London)	1	19	19	46	899	63	35	17
England, south-west	0	9	8	34	581	34	10	6
England, north-west	0	6	3	25	490	27	17	13
Wales, north	0	2	3	15	282	9	3	1
Wales, south	0	6	9	16	365	22	7	5
Isle of Man	0	2	0	1	20	3	1	2
Scilly and Channel Isles	0	3	0	3	22	7	1	2
Northern Ireland	0	8	7	44	310	25	24	9
Total	3	122	94	426	6805	419	211	125

* Includes stations in earlier columns.

TABLE V—HEIGHTS REACHED IN UPPER AIR ASCENTS

The following table shows the number of upper air ascents giving observations of (*a*) temperature, pressure and humidity and (*b*) wind, which have reached specified heights, and the height performance of the largest balloons.

(*a*) Observations of temperature, pressure and humidity

	Number of observations	Percentage of all balloons reaching				Percentage of largest balloons reaching
		100 mb 16 000 m (approx.)	*50 mb 20 000 m (approx.)*	*30 mb 24 000 m (approx.)*	*10 mb 30 000 m (approx.)*	*10 mb 30 000 m (approx.)*
Eight stations in the U.K.	5834	85·2	61·2	31·6	10·2	68·4
Seven stations overseas	4741	90·5	63·4	27·5	6·5	63·8
Four Ocean Weather Ships	1461	88·2	66·6	27·7	0·6	—

(*b*) Observations of wind

	Number of observations	Percentage of all balloons reaching				Percentage of largest balloons reaching
		100 mb 16 000 m (approx.)	*50 mb 20 000 m (approx.)*	*30 mb 24 000 m (approx.)*	*10 mb 30 000 m (approx.)*	*10 mb 30 000 m (approx.)*
Eight stations in the U.K.	11 573	78·7	47·3	18·5	5·5	72·4
Seven stations overseas	8 349	84·1	52·4	20·7	4·2	69·9
Four Ocean Weather Ships	2 818	80·2	50·3	18·3	0·2	—

TABLE VI—THUNDERSTORM LOCATION

Number of thunderstorm positions reported by CRDF network:

In 1969 .. .. .. 73 892

TABLE VII—METEOROLOGICAL COMMUNICATIONS TRAFFIC

Almost all the national and international exchanges of meteorological data, which are used in the construction of synoptic charts and the production of forecasts, are effected by coded messages. The coded messages are composed of groups of five figures and there may be from 5 to 90 such groups in one message. The messages are exchanged by radio and land-line facilities. In addition there is an exchange, both nationally and internationally, of meteorological information in pictorial format. This information is largely analyses and forecasts derived from processing observational data. The transmission method is analogue facsimile by either radio or land-line.

The following figures give an analysis of the traffic through the Meteorological Office Telecommunications Centre for one typical day (24 hours) taken near the end of December 1969 and, for comparison, some corresponding figures are given for one day near the end of 1968.

	In	Out	Total	Total in 1968
Coded messages		*number of groups in one day*		
Land-line teleprinter	471 338	329 983	801 321	740 075
Radio	181 361	246 530	427 891	457 644
Facsimile charts		*number of charts in one day*		
Land-line	98	466	564	585
Radio	83	138	221	216

TABLE VIII—SPECIAL SEASONAL FORECASTS

There is a need for forecasts of a special type at certain seasons. These are described in Met. O. Leaflet No. 1 (1968). The numbers receiving such specialized services are as follows:

	Year	No. of customers	Year	No. of customers
Fine-spell notifications (a summer service primarily for farmers)	1968	505	1969	425
Week-end temperature forecasts (a winter service primarily for industrialists) ..	1968–69	35	1969–70	35
Snow and icy-road warnings (primarily for local authorities)	1968–69	354	1969–70	365

TABLE IX—FORECASTS FOR AVIATION

Forecasting for aviation constitutes the primary function of many of the offices. The Central Forecasting Office is mainly concerned with analysis of the weather situation, the issue of guidance in outline to other offices and the issue of forecasts to the BBC and the national Press. Thus the volume of work in the Central Forecasting Office shows little variation from year to year. The following figures indicate the numbers of forecasts issued for aviation and the numbers of meteorological briefings that took place during 1968 and 1969. They do not include warnings and routine general forecasts.

	1968	1969
Number of meteorological briefings for		
aviation in the U.K.	394 217	396 896
aviation at overseas stations	55 907	59 805
Number of aviation forecasts issued for		
aviation in the U.K.	1 073 364	1 144 021
aviation at overseas stations	272 004	302 202

TABLE X—NON-AVIATION INQUIRIES

Non-aviation inquiries are handled by five weather centres in London, Manchester, Glasgow, Southampton and Newcastle and one other office in Nottingham (Watnall) whose function is to meet the needs of the general public for forecasts for special purposes. Many other forecast offices, established primarily to meet the needs of aviation, also answer telephone requests for forecasts and other weather information, from the general public, Press, public corporations, commercial firms, etc. (The *Post Office Guide* lists 37 offices providing forecasts for the general public.) These inquiries, most of which refer to current or future weather, are listed according to the purpose of the inquiry in the figures below.

	1968	1969
Grand total of inquiries (all figures)	1 480 262	1 610 484
Percentage of inquiries connected with		
agriculture, etc.	11·1	9·4
building	6·0	6·1
commerce, industry	5·3	5·1
holidays	19·0	18·4
marine matters	14·4	13·5
Press	8·9	9·4
public utilities	8·5	8·5
road transport	10·0	14·5

TABLE XI—FLASH WEATHER MESSAGES

FLASH weather messages are passed to the BBC for broadcast on sound channels, and to the BBC and most Independent Television Companies for inclusion in their programmes at a convenient break. They are, effectively, warnings of the actual occurrence of weather conditions which might cause considerable inconvenience to a large number of people. The following table shows the kind of weather and areas of the country for which FLASH messages are broadcast and the number issued in 1969.

Area	Dense fog	Moderate or heavy snow	Heavy rain	Glazed frost or icy roads	Severe inland gales	Wind in coastal waters
Edinburgh and south-east Scotland	3	3	3	—	2	—
Glasgow and south-west Scotland	3	1	4	—	3	—
Belfast and Northern Ireland	2	1	1	—	—	—
Industrial north-east England	—	3	3	1	1	—
Industrial Lancashire and Merseyside	2	—	—	—	1	—
Industrial Midlands	2	5	5	2	—	—
Bristol and Bath	—	—	3	—	—	—
South Wales	—	1	5	—	1	1
London and south-east England	—	1	2	1	—	—
Plymouth and south-west England	2	—	2	1	—	—
Yorkshire	1	3	7	—	—	—
Southampton and Portsmouth	2	2	6	—	—	1
Total	17	20	41	5	8	2

In addition warnings of a more general nature relating to dense fog (3 occasions), snow (1 occasion), heavy rain (3 occasions) and inland gales (1 occasion) were issued.

TABLE XII—AUTOMATIC TELEPHONE WEATHER SERVICE FORECASTS

The total number of calls made on the service during 1969 showed an increase of 24 per cent over the previous year. Forecasts were made available at 3 more GPO Information Centres bringing the total of such Centres to 46. The number of forecast areas remains at 23.

Information Service Centre	Forecast area	Number of calls 1968	1969	Remarks
London	London	3 360 216	3 687 250	
London	Essex coast	177 796	214 396	
London	Kent coast	184 516	183 750	
London	Sussex coast	288 441	280 263	
London	Thames Valley	103 300	203 017	
Colchester	Essex coast	161 206	192 213	
Brighton and Hove	Sussex coast	313 170	433 117	
Birmingham	Birmingham	523 466	664 470	
Liverpool	South Lancashire and north Cheshire	258 702	305 428	
Liverpool	Lancashire coast	70 818	82 828	
Liverpool	Chester and north Wales coast	57 141	56 335	
Manchester	South Lancashire and north Cheshire	284 243	363 608	
Manchester	Lancashire coast	54 573	64 971	
Manchester	Chester and north Wales coast	34 860	47 897	
Cardiff	Cardiff	293 182	305 658	
Belfast	Belfast	221 781	239 469	
Glasgow	Glasgow	374 348	414 511	
Edinburgh	Edinburgh	261 422	225 623	
Bristol	Bristol	344 042	409 286	
Portsmouth	South Hampshire	179 299	210 103	
Southampton	South Hampshire	206 058	251 589	
Canterbury	Kent coast	136 662	177 335	
Blackpool	Lancashire coast	153 010	173 669	
Southport	Lancashire coast	55 863	62 097	
Plymouth	South Devon and east Cornwall	134 789	148 659	
Exeter	South Devon and east Cornwall	74 951	94 270	
Newcastle	Tyne, Tees	190 467	224 677	
Blackburn	Central Lancashire	86 454	115 881	
Blackburn	Lancashire coast	40 146	50 553	
Bournemouth	South Hampshire	106 124	239 513	
Nottingham	Nottinghamshire, Derbyshire, Leicestershire	242 428	358 401	
Leicester	Nottinghamshire, Derbyshire, Leicestershire	138 186	206 064	
Middlesbrough	Tyne, Tees	70 573	96 694	
Oxford	Thames Valley	110 195	123 457	
Colwyn Bay	Chester and north Wales coast	46 155	60 700	
Gloucester	South-west Midlands	57 679	90 355	
Cheltenham	South-west Midlands	31 025	47 479	
Tunbridge Wells	London	22 907	45 419	
Southend	Essex coast	52 317	83 656	
Chelmsford	Essex coast	28 553	54 245	
Bedford	40 miles radius of Bedford	79 910	123 270	
Reading	Thames Valley	106 218	163 271	
Hereford	South-west Midlands	14 870	34 324	
Bradford	Leeds, Bradford, Huddersfield	19 955	59 985	
Leeds	Leeds, Bradford, Huddersfield	97 481	181 712	
				Opened
Torquay	South Devon and east Cornwall	38 472	53 153	March 1968
London	40 miles radius of Bedford	25 183	55 493	May 1968
Sheffield	Sheffield, Chesterfield, Doncaster, Barnsley	53 065	157 754	June 1968
Medway	Kent coast	11 026	35 416	July 1968
Chester	Chester and north Wales	13 129	73 985	August 1968
Guildford	London	9 547	56 758	August 1968
Peterborough	40 miles radius of Bedford	6 186	38 815	September 1968
Huddersfield	Leeds, Bradford, Huddersfield	10 771	48 428	October 1968
Coventry	Birmingham		18 790	February 1969
Doncaster	Sheffield, Chesterfield, Barnsley, Doncaster		9 712	July 1969
Swindon	Bristol		1 699	December 1969
Total		10 016 877	12 401 471	

TABLE XIII—CLIMATOLOGICAL INQUIRIES

Most of the inquiries dealt with by the offices outside Headquarters refer to current weather or to forecasts. Met.O.3, Met.O.8, Edinburgh and Belfast receive a number of inquiries relating to past weather, to climatology and to the application of meteorological data to agriculture. The following figures give the total number of inquiries and the percentages of this number arising from various categories.

	1968	1969
Total number of climatological inquiries	13 610	13 813
Percentage relating to		
agriculture (farming, forestry, market gardening)		12·5
building and design (including siting)		20·7
commerce (sales, marketing, advertising)		3·7
drainage		1·6
education and literature		6·6
flooding		0·7
heating and ventilation		2·0
industrial and manufacturing activities		5·4
law (damage, accident, insurance)		14·6
medical and health		1·8
Press and Information Centres		3·6
research		6·1
sport, hobbies, holidays		1·3
transport and communications		1·6
water supplies		7·3
miscellaneous (purpose known)		4·8
miscellaneous (purpose unknown)		5·6

TABLE XIV—DATA PROCESSING

(*a*) Punched-card installation

Number of cards punched by the Meteorological Office installation	1 095 304
Number of cards punched elsewhere on behalf of the Meteorological Office	169 257
Number of cards converted to paper tape	194 750
Number of cards converted from paper tape	168 118
Number of non-routine investigations completed	174

(*b*) Computer installation

The electronic computer COMET was used for computing during 7418 hours.

TABLE XV—INSTRUMENT TESTING AND CALIBRATION

The numbers include those of instruments tested or calibrated for outside authorities on repayment.

	Number of tests or calibrations
General meteorological instruments	62 675
Balloons	97 675
Radiosonde batteries	20 040
Radar reflectors	33 380
Electrical/electronic instruments and components	19 691
Radiosondes, calibrated	17 765
Total	251 226

In addition 1880 radiosondes were recovered after flight and 61 per cent of these were repaired and recalibrated for further use.

THE DIRECTORATE OF RESEARCH

Special Topic—Studies of Geophysical Motions with Laboratory Models

Introduction

The air motion in the atmosphere and the currents in the ocean are controlled by the basic laws of fluid dynamics, which are well understood. Nevertheless the motions occurring naturally in the air and sea are so complicated that it is difficult to trace a logical sequence of cause and effect through a series of dynamical phenomena in the atmosphere or oceans without undertaking elaborate and expensive calculations. Even to adopt this mathematical approach requires a simplification of the problem by omitting factors which are considered to be irrelevant, and it is difficult to be sure that some important factor has not been left out.

In laboratory research into physical phenomena an important aid to understanding is the ability which the scientist has to vary the conditions under which the phenomena are produced. Such a facility is not available to the meteorologist or the oceanographer; he is not able to vary the conditions under which the natural phenomena occur, and although he may observe similar phenomena in somewhat varying circumstances, he is not able to assure himself that any variations in the phenomena are indeed produced by the factors to which he attributes them. The laboratory physicist on the other hand can repeat his experiments many times until he is satisfied as to the sequence of cause and effect.

It is appropriate, therefore, to consider whether laboratory experiments can be used to simulate phenomena of the atmosphere and ocean sufficiently closely to help to provide an understanding of the natural phenomena. It appears that they can be so used, and a branch was set up within the Meteorological Office in 1967 with the aim of exploiting laboratory models of fluid motions. The work of the branch has been designed to build on the experience of research groups who had already been studying such fluid models in the U.S.A. as well as in this country and the Meteorological Office has been fortunate to have as leader of its team Dr R. Hide who had previously been engaged on similar research at the Massachusetts Institute of Technology.

It is important to realize that any laboratory model is a very imperfect representation of the atmosphere or ocean. Several important features (e.g. the radially directed gravitational force) cannot be reproduced in the laboratory. Thus, the purpose of the laboratory work is to provide strictly controllable experiments in which motions similar to those of the atmosphere can be produced and fully understood, and not to produce a small-scale model of the atmosphere or ocean which can directly be interpreted in terms of natural motions in the real environment. The model cannot be simply 'scaled-up' as if it were an aircraft model in a wind-tunnel.

The laboratory work must therefore be supported by theoretical understanding of the behaviour of the model and the studies have applications to

many natural motions other than those of terrestrial meteorology and oceanography. These include the motions of the atmospheres of other planets and of the fluid interior of the earth. The Meteorological Office branch which undertakes these studies is known as the Geophysical Fluid Dynamics Laboratory.

Laboratory models of thermally induced motion in rotating systems

It has proved to be possible to produce many of the important features of the large-scale circulation of the atmosphere by using water contained in a rotating cylindrical pan. The water is heated at the outer edge and cooled near the axis, thus providing a simulation of the temperature gradient between the pole and equator.

Plate I shows the flow pattern on the upper surface of such a model made visible by aluminium powder on the surface, and compares this with a typical flow pattern for the large-scale air motion in the upper troposphere of the northern hemisphere as illustrated by a typical 500-mb chart. Similarities in the large-scale wave-like pattern of the main current are immediately apparent and in both systems the main transport is concentrated into a relatively narrow current—the 'jet stream' in the atmosphere.

Plate II shows a variety of such flow patterns which can be produced at the upper surface of the water in a rotating annulus which is heated at its exterior and cooled in the central core. The experimental conditions can be accurately controlled and the occurrence of the various types of motion can be related to the rate of rotation, the magnitude and form of the heating and cooling, the dimensions and shapes of the bounding surfaces and the viscosity, thermal conductivity and coefficient of expansion of the experimental fluid. Four fundamentally different types of flow have been identified and it is possible to determine the characteristic fields of temperature and motion throughout the fluid which accompany them.

Plate IV shows apparatus set up in the Meteorological Office, Bracknell, to carry out experiments of this character. In a recent series of experiments on a smaller annulus the fluid was heated internally by passing an electric current through it. It was possible to demonstrate how the fluid motion responded to an internal rather than an external heat source, and thus establish some important generalizations regarding the role which the jet-like currents play in the transport of heat within the system.

The significance of these experiments for meteorology lies primarily in the fact that they demonstrate the circumstances under which certain types of flow may occur, and show quantitatively the role of various factors in controlling the flow régime. It has been possible to show which are major controlling factors and which have only a minor influence. The fact that phenomena such as the jet stream, cyclones and fronts have close parallels in the laboratory model shows that condensation of water vapour and consequent release of latent heat has only a secondary role in the occurrence of these phenomena in the atmosphere. Similarly the parallel between the wave-like distortions of the current in the model and the atmosphere suggests that the so-called 'beta effect', arising from the change of Coriolis parameter with latitude on the earth but absent in the model, plays a lesser role than was at one time supposed in the establishment of the long-wave pattern of the flow in the atmosphere.

These experiments provide a context in which strictly quantitative and controlled studies can be carried out with relevance to the general circulation of the atmosphere of the earth and other planets.

Detached shear layers

Amongst the more remarkable features of the atmosphere and oceans are strong shearing motions which are found in places where they are clearly not directly produced by the influence of an adjacent boundary. Fronts and associated jet streams are familiar examples to meteorologists, but the equatorial jet-like currents in the oceans and in the atmospheres of Saturn and Jupiter are others. Jupiter's red spot is similarly associated with apparent shear at its edges. The widespread occurrence of these phenomena suggests that they are a natural consequence of the laws of fluid motion applied to rotating fluids.

One of the recent developments in the use of fluid models has been the study of detached shear layers and of associated boundary layers under the simplest possible conditions. The theoretical interpretation of the results enables the corresponding mathematics to be developed with the minimum number of irrelevant considerations. Plate III shows the formation of shear layers detached from the edge of a disc moving slowly relative to a rotating fluid. The photograph was taken several minutes after the commencement of the release of dye from the rim of the disc.

Techniques

It was sufficient in most of the aforementioned experiments to determine no more than the broad characteristics of the pattern of flow. This can be done with the aid of quite simple flow-visualization techniques, involving the use of dyes (e.g. fluorescein) or tiny reflecting particles (e.g. polystyrene beads or aluminium powder) either in suspension or floating on the top surface.

In principle the horizontal velocity field is readily found at any level by illuminating the suspended particles with a flat beam of light aimed at that level and obtaining streak photographs of the horizontal trajectories of illuminated particles by exposing the film, usually for several seconds, in a camera on the rotating apparatus. Streak photography has been applied mainly to the study of top-surface flow patterns. It has not yet been used extensively for obtaining three-dimensional velocity fields (although visual work with flat horizontal and vertical light beams has proved instructive in this connection), but the technique increases in feasibility as methods of automatic data processing improve and ought therefore to be considered more seriously in future work. Typical flow speeds fall within a range that precludes the application of most available anemometer techniques, but progress with the adaptation of thermistors for this purpose has been reported recently.

For the study of the temperature distribution of the thermally driven motion in a rotating annulus a single thermocouple, or a modest array, has proved adequate, provided that the motion was steady or only slowly changing. As more complicated motions are studied, however, more complex arrays of sensing elements will be needed and substantial problems of data processing may have to be faced.

Accurate direct determinations of total heat transfer and of local heat transfer over limited areas of the bounding surfaces are also comparatively

easy to make, provided that adequate precautions are taken to eliminate spurious heat losses, but limited attempts to measure net and local momentum transfer directly have not yet proved successful.

Numerical treatment of fluid dynamics

As has been described in the *Annual Reports* for 1967 and 1968, numerical integration of the equations of motion is being applied directly to the study of the general circulation of the atmosphere and to the forecasting of weather day by day. In view of our limited knowledge of atmospheric processes and our lack of data which would fully describe the atmosphere at one particular time, it is impossible to know the causes of the discrepancies which arise in numerical integrations of the equations of atmospheric dynamics. The causes may be principally in our failure to include certain atmospheric processes, or in our failure to integrate accurately the equations describing the processes which have been included. Alternatively the failures may be due to the inadequacies of the description of the weather situation from which the integration was started.

Such uncertainties are much less important in controlled laboratory experiments, and thus the application of similar numerical methods to the description of the motion in corresponding laboratory models may in future provide not only an improved understanding of the phenomena in the models, but also an improvement in the methods of calculation and mathematical representation applicable both to the models and the real atmosphere.

Physical Research

Cloud dynamics

Substantial efforts were devoted to the study of the detailed air motion in rain systems as they approach the British Isles across the Isles of Scilly. The second phase of Project Scillonia was carried out in January when two warm fronts were investigated on the 17th and 19th. On both occasions the vertical motions on three main scales were measured simultaneously by the following techniques:

(i) On the 300-km scale by isentropic analysis of the conventional radiosonde network, supplemented by extra soundings.

(ii) On the 20–80-km scale by measurements of the convergence of the horizontal wind field within the frontal rain. The wind fields were obtained by means of automatic-opening radar reflectors, ejected from the Meteorological Research Flight Varsity in a predetermined pattern and followed by precision tracking radars based on St Mary's Airport, Isles of Scilly.

(iii) On the 10–20-km scale, again by measurements of the convergence of the horizontal wind. On this scale, the wind measurements were made by the mobile Doppler radar which measures the speed of the precipitation particles which can be regarded as tracers for the horizontal wind motion.

Limited details of the precipitation distribution over the sea around the Isles of Scilly were obtained by means of a conventional precipitation radar.

The correlation between the vertical air motions and the distribution of precipitation was studied and the subsequent development of the precipitation as it moved over the mainland was also investigated by a detailed analysis of all the rain-gauge records in England and Wales. The results are yielding unique information on the dynamical structure of the two fronts so intensively studied.

Radar echoes in clear air

In recent years it has become apparent that some types of radar echoes detected in clear air at heights up to and sometimes above 10 km are due to scattering from irregularities in refractive index. The strongest clear-air echoes occur at the boundaries of convective elements and also within inversions and other shallow stable layers throughout the troposphere. Given a sufficiently powerful radar of an appropriate wavelength it is possible to observe the three-dimensional structure and evolution of patterns of clear-air convection and also the structure of inversions and the evolution and occasional breakdown of strongly sheared stable layers.

In order to exploit this observational technique the Meteorological Research Unit, Malvern, has installed a high-power 10-cm radar transmitter for use in conjunction with one of the 25-metre diameter parabolic reflectors at the Royal Radar Establishment, Defford. These reflectors, originally designed and indeed still used for radio astronomy work, are fully steerable and provide both a high gain and an unusually good spatial resolution. The first successful meteorological observations of clear-air echoes with this facility were made in October and November 1969 and these revealed undulating layer echoes out to a maximum range of 60 km associated with the top of a low-level inversion. (See Plates VI and VII.)

Cloud physics

In an analysis of large hailstones (diameter 7 cm) collected on 1 July 1968, the isotopic composition of the ice (DHO/H_2O and $H_2{}^{18}O/H_2{}^{16}O$ ratios) was measured and compared with the bubble and crystalline structure with the assistance of the French Atomic Energy Laboratories at Saclay. The results show that the stones made two traverses through the storm updraught with vertical velocities within the storm as high as 50 m/s.

Experiments to investigate the influence of wind shear on the coalescence of small cloud droplets have shown a large increase in the coalescence efficiency when compared with the results in still air. This work could have profound effects on our understanding of the factors controlling the initial growth of cloud droplets in turbulent clouds.

A world-wide project, involving laboratories in 17 countries, was carried out in January and February 1969 to investigate the spatial and temporal variations in the concentrations of freezing nuclei. (These are small particles which, when incorporated into small supercooled droplets, will induce them to freeze.) Samples were collected by filtering known volumes of air and these filter samples were processed either at our laboratory in Bracknell or at those of the Commonwealth Scientific and Industrial Research Organization (CSIRO), Australia. The results show comparatively little variation between concentrations in polluted atmospheres such as those in Chicago and New York and in rural regions such as Papua in New Guinea and the vicinity of Mount

and in rural regions such as Papau, New Guinea and the vicinity of Mount Fuji, Japan. In fact the range of concentrations was very similar to that observed in the British Isles. The concentrations of freezing nuclei were consistently lower than the concentrations of ice crystals known to exist in natural clouds at moderate temperatures. This anomaly concerning the number of freezing nuclei and the number of ice crystals in the atmosphere is the subject of continuing research on ice-splintering processes in the atmosphere and the mode of operation of freezing nuclei.

Meteorological Research Flight

The Flight is now equipped with a Varsity and a Canberra aircraft. The Varsity aircraft was replaced at the end of the year because of its age by another Varsity which had been refurbished. The replacement Varsity will have a Doppler radar, a facility which was not available in the older aircraft.

The Canberra aircraft installation was also extended in the autumn by the addition of an analogue Doppler inertial-mix facility for the stable platform which should materially reduce the drift rate of the platform.

A feasibility study has been initiated in regard to the equipping and modification of the Hercules aircraft (to become available for modification in mid-1970). A revised specification for the magnetic-tape digital recording system was completed early in the year and tenders for the manufacture of the equipment were received. The contract should be allotted at an early date.

Both the Canberra and the Varsity aircraft took part in Project Scillonia in January, the Varsity dropping radar targets, the Canberra carrying out weather reconnaissances and providing accurate wind measurements below the level of use of the radar targets. The Varsity aircraft was detached to Malta in July to undertake measurements of sea temperature with the radiation thermometer in conjunction with studies of the thermal structure of the upper layer of the sea.

A proposal to measure and count precipitation drops in large numbers using a fibre-optics method has been demonstrated in the laboratory and is now being developed for aircraft use.

High atmosphere

Experiments to measure ozone density were successfully carried out on two BLACK BRANT rockets at Fort Churchill, Canada, in September 1969 in conjunction with airglow experiments carried out by the University of Saskatchewan. Experiments have been designed in which the density of molecular oxygen will be measured as well as the ozone density. These will be flown on SKYLARK rockets at the European Space Research Organization range at Kiruna, Norway, and at Woomera, Australia, early in 1970. The Woomera rockets will also carry an experiment for measuring water vapour density.

Very much more of the molecular oxygen data from the satellite ARIEL 3 proved to be of good quality than was at first thought, and analysis of these has continued and is nearing completion. These results show that there are large longitudinal variations in the concentration of molecular oxygen at levels around 180 km, and they appear to be correlated with geomagnetic activity.

Two further SKYLARK rockets have been launched at Woomera carrying molecular oxygen experiments; these have been varied from previous experiments in order to clear up some uncertainties arising from the behaviour of the ionization chambers.

As in the previous winter a high-level warming took place in the first half of December 1968, when the stratopause temperature rose from −17°C on the 9th to +36°C on the 14th (at approximately 42 km above sea level), but severe restrictions on the launching of SKUA rockets at the Royal Artillery range in the Hebrides, following the finding of a small part of a rocket on the land earlier in the year, prevented any more soundings until the end of the month, when more normal conditions were established. Modifications which greatly strengthen the SKUA rockets are now being carried out. In a recent campaign 10 rockets were launched at Gan during a three-week period in April and May and a further 3 rockets were launched in September. These showed that layers of westerly winds alternate with layers of easterlies, with westerlies at the highest levels (above 50 km).

Progress has been made in an experiment being carried out in conjunction with Oxford University for measuring the airglow of molecular oxygen, and it is expected that these will be carried on two SKUA 2 rockets to be launched in the Hebrides early in 1970.

Laboratory tests on modified Brewer–Mast ozone sondes have been completed, and plans are being made to start regular flights with them in 1970. No requests were made in 1969 for the calibration of new Dobson ozone spectrophotometers, for which the Meteorological Office has a responsibility to the World Meteorological Organization.

Equipment for measuring winds at 80 to 100 km by the motion of ionized meteor trails is being constructed, and it is hoped that measurements will begin in the spring of 1970.

Observatories

Following the transfer of the geophysical observatory at Eskdalemuir to the Natural Environment Research Council in 1968, six members of the Meteorological Office staff have continued to work there for the purpose of maintaining the meteorological observations. At Lerwick Observatory, which remains within the Meteorological Office, the geomagnetic observations are now undertaken by two members of the staff of the Natural Environment Research Council.

Publication of the Meteorological Office *Seismological Bulletin*, prepared by Kew Observatory, which commenced in January 1927, ceased with the issue in April of the bulletin for December 1967. Responsibility for the publication of seismological data recorded at Eskdalemuir from 1 January 1968 rests with the Institute of Geological Sciences, (NERC), Edinburgh. Seismological work ceased completely at Kew with the ending of recording by the last seismograph there on 1 April.

The bicentenary of Kew Observatory on 3 June 1969 was commemorated by a special issue of the *Meteorological Magazine* for June 1969, and the associated

article 'Kew—the National Radiation Centre' appeared in the July issue of the *Meteorological Magazine*. The last Meteorological Office *Observatories' Year Book*, that for 1967, has been published.

Boundary layer studies

The high-frequency turbulent wind fluctuations have been measured from a balloon cable up to 900 m on a considerable number of occasions. During the latter part of the year similar turbulent fluctuations of temperature have also been measured and some ascents have been made during which simultaneous observations have been made at two levels. Comparative measurements of wind from an aircraft of the Meteorological Research Flight, from the captive balloon and from pilot-balloon ascents have also been made to establish the representativeness of wind profiles in the first kilometre. This observational programme is designed to study the distribution of turbulence in the lower atmosphere, including levels at which the earth's rotation has significant effects on the wind structure.

Performance tests have revealed some deficiencies in the equipment used for sensing turbulent wind fluctuations. The system has been redesigned and more accurate results have been obtained. Prototype equipment has been built for measuring wind direction fluctuations from a balloon cable. Preparations continue for collaboration in the first stage of the Royal Society experiment in the North Atlantic in June 1970 near Ocean Weather Station J, in latitude 52° 30'N, longitude 20°W, when it is planned to fly up to four turbulence-measuring packages simultaneously at heights ranging to at least 500 m.

Numerical methods are being employed for the theoretical study of the distribution of turbulence in the lowest kilometre or so of the atmosphere and of its effect on the variation of wind with height in this layer. Numerical methods are also being used for the prediction of vertical diffusion of material released into the atmosphere under various stability conditions.

Plans have been agreed for the use of the Cardington captive-balloon technique in conjunction with an extensive installation of equipment for measuring turbulence near the ground maintained by the Boundary Layer Branch of the U.S. Air Force Cambridge Research Laboratories over the next few years. Instrument comparisons were carried out in Boston in October. Further comparisons with high-tower installations are planned for 1970 and a comprehensive field experiment in Kansas is planned for 1971.

Measurements of evaporation from a field of barley were made during 1969 and good agreement obtained between independent methods of assessing water losses from the crop. This work is conducted in co-operation with the Nuffield project for the study of the growth of barley in drought conditions.

The study of the thermal structure of the upper layers of the sea has continued and the occurrence of turbulence in thermally stable layers has been studied both observationally and theoretically. The Varsity aircraft of the Meteorological Research Flight co-operated with a Royal Air Force launch in locating areas across which there are strong horizontal gradients of sea temperature. Measurements of the vertical distribution of temperature in these regions were made from the launch and they reveal structures similar in some respects to fronts in the atmosphere.

Geophysical fluid dynamics

A large rotating annulus which was constructed for Dr Hide when he was a Professor at Massachusetts Institute of Technology has now been set up in the Meteorological Office. Experiments conducted in this and smaller rotating pans have enabled studies to be made of the dependence of the circulation of rotating fluids on the upper and lower boundary conditions. The effect of providing an electrical source of heat within the body of the fluid instead of at the boundaries has been studied, and this has provided experimental confirmation of certain theoretical principles governing the circulation of fluids in rotating pans when subjected to heating and cooling.

An experiment was set up to determine whether a heat source which moves round a circular pan of fluid will set up strong circulations. The heat source simulates the daily cycle of solar heating which the sun applies to the atmospheres of the planets. The experiment is particularly relevant to theories of the circulation of the atmosphere of the planet Venus.

Dynamical and Synoptic Research

Research related to short-range weather forecasting

One of the most important meteorological tasks is that of predicting the weather for a day or two ahead and a considerable research effort has been directed to improving and extending the forecasts. The most promising line of research, which has received the major part of our effort, is that in which the behaviour of the atmosphere is represented in mathematical terms by writing down the equations of motion and energy. These are highly complicated, non-linear partial differential equations which in principle allow us to predict the wind and pressure fields in the atmosphere from a knowledge of the fields at a given time. Analytical solutions to the equations are not known, so their integration has to be carried out numerically using high-speed computers. Routine computations of this kind have been in operational use for a number of years and are described in the Special Topic of the Directorate of Services in the *Annual Report* for 1968.

During 1969 further progress has been made with the development of a numerical prediction scheme which is designed to give more detail in the forecasts. The success of such a scheme depends largely on recognizing the physical processes which affect the development of weather situations and then representing them mathematically in the computational scheme. The computation as now developed takes into account the effects of water and water vapour in the atmosphere, of frictional stress with the earth's surface, topography, overturning of the air in convective clouds, large-scale diffusion and of turbulent transfer and radiation effects near the surface. The resulting predictions are of temperature, wind and humidity at 10 levels in the vertical at each intersection of a square grid of grid-length about 60 nautical miles. The rainfall at each of these grid points is also computed. An extensive restructuring of the programme was carried out in the first half of the year which resulted in halving the computing time, but the computation still remains so formidable as to occupy the whole resources of the Science Research Council's Atlas computer for $4\frac{1}{2}$ hours in carrying out a 24-hour forecast. A considerably more powerful computer would be required to make the computations on an operational basis.

The preparation of observational data in a form suitable for starting the prediction computation presents problems of objective analysis which have not yet been completely solved, although successful computer programmes have been prepared for the analysis of contour heights of the pressure surfaces, and methods are being developed for the objective analysis of the humidities at each level. It has become clear that the success of the predictions may depend on a close interrelation between the wind and pressure fields at the start of the computation, and methods of obtaining this initial balance are being investigated.

Several forecasts have been made for up to 24 hours for an area centred on the U.K. and of radius about 1500 miles, the forecasts being repeated as necessary when the computational scheme has been changed owing to the introduction of new expressions of physical processes; the results are most promising, and a test under operational conditions is confidently expected to yield good results.

Work was completed on the development of the technique of numerical forecasting used in the daily routine forecast computations in order to extend the forecast to five days. This required that the computations be also extended to refer to the whole northern hemisphere. The success was limited and the effort was transferred to developing the 10-level model described earlier to apply to the northern hemisphere as a whole by increasing the grid-length threefold. The necessary computer programmes have been written and the initial data extracted for one occasion. The computations were successful and the forecast carried to 72 hours with encouraging results, although several problems remain to be solved. These are chiefly connected with the wider range of surface conditions and topographic heights in dealing with this larger area. Modifications of the analysis programmes to suit the hemispheric area are in hand.

Attention has been paid to assessing the average rainfall over grid squares with sides of about 100 km from all the rainfall observations relating to the square. The main object is to use those assessments in verifying the rainfall predicted by the 10-level model but the method is expected to have a wider use including applications to hydrology.

Experimental forecasts for seven days ahead have been made at the beginning and middle of each month, based partly on the available numerical prediction for 72 hours ahead and partly on the weather which followed on previous occasions when the 500-mb contour charts resembled those of the last five days. The forecasts have shown an encouraging degree of success.

The staff at outstations continue to show great interest in problems of local forecasting and have pursued such diverse questions as the way in which the visibility and frequency of occurrence of low cloud varies with wind direction, and the prediction of night minimum temperatures, including those at a road surface. New studies include an investigation into the occurrence of unexpectedly strong winds on the Cairngorm ski slopes in conditions which are apparently suitable for the formation of lee waves. These investigations often lead to a revaluation of current techniques of forecasting local weather and the introduction of new methods which have been devised and tested elsewhere.

Research related to long-range forecasting

Weather forecasts for a month ahead are prepared at the beginning and the middle of each month and are made available to the public through Press and broadcasting media. More than 2000 subscribers receive, for a small charge, a more detailed copy of each forecast together with statistical information about the month in question. It is not possible to provide a detailed forecast, as given for short periods of a day or two, for a month ahead and these monthly forecasts indicate for each of the 10 regions of the *Monthly Weather Report* the expected mean temperature anomaly in one of five categories and the expected mean rainfall in one of three. The limits of these categories are chosen so as to render the categories equally likely over a long run of months. The broad weather sequence is also predicted with special mention of any expected outstanding features such as a higher than usual number of foggy or snowy days. The slight improvement in the standard of accuracy of long-range forecasts noted over the last two years has continued and there has been an increase in the number of commercial companies, manufacturing or distributing such weather-sensitive products as ice cream and fuel oil, who are trying to make use of the monthly forecasts of temperature in estimating demands for their products.

In principle the method of making monthly forecasts (see Meteorological Office *Annual Report* 1965, pp. 47–54) has remained unchanged. Briefly the method is to match the weather of the last 30 days with that of similar periods in the past at the same time of year and to base the forecast on the known sequels of the analogue periods. For success it is essential that past weather records over a wide area be available for as many years as possible in a form suitable for use in a computer; the Meteorological Office library of past records and processed data is now practically complete back to 1873 and it is unlikely that much new data which can be useful on a hemispheric scale will come to light. The matching process has been applied to the charts of mean monthly temperature and pressure and daily weather sequence. The extension of the data library has increased the number of years from which analogues may be chosen and extended the technique of matching to mean monthly 500-mb contours, sea surface temperature and indices designed to categorize the synoptic character of the month. During the year a good deal of attention has been paid to the relationship between the mean monthly sea surface temperature anomaly in the North Atlantic Ocean and anomalies in the atmospheric circulation revealed by pressure and temperature distribution in the following month. For each month of the year the probable circulation anomaly patterns following well-defined sea temperature anomaly patterns have been established and it is likely that the results of this research are responsible for the improvement in the standard of accuracy of the monthly forecasts.

Research has continued into extending the methods used in making monthly forecasts to make seasonal forecasts. The task seems more difficult because there is usually more variation within a season than within a month and experience in seasonal forecasting is acquired more slowly than in regard to 30-day forecasts issued twice a month. Trial forecasts were made for winter, spring and summer of 1969 and each showed a measure of success. The forecast for spring was a new departure, made possible mainly as a result of some research into the relation between winter in the Iceland and Baltic Sea regions and the following spring weather in Britain. Research into the expected movement of

the monthly mean trough position at 500 mb from one season to the next has also proved helpful in seasonal forecasting. A comprehensive account of the unusual summer of 1968 and of the factors which led to it was prepared and published.

The examination of processed data and the preparation for the monthly and seasonal forecasts have been simplified by the development over the last few years of a specially designed computer language which has been finalized and documented. This simple language has allowed the survey and manipulation of hemispheric data covering many years and has, in addition, allowed the development of sophisticated techniques of analysis by determining the natural characteristic patterns of pressure and temperature fields. These analyses are expected to play a great part in classifying meteorological data and in bringing to light relationships between the various weather elements. Some advances in statistical theory and practice as applied in meteorology have been made and published.

Climatic change

The study of climatic change is important because it reveals the different weather régimes that have existed in the past and may provide indications of future change. Direct observational evidence is only available from the 16th century onwards and in abundance only during the last hundred years. For earlier periods the meteorologist is forced to infer the atmospheric circulations from indirect evidence provided mainly by botanical, archaeological and oceanographic studies using the most modern physical dating methods. Tentative mean 1000–500-mb thickness charts have been derived for several different stages of the last ice age and used to derive probable surface pressure distributions. The results seem to throw light on the manner of onset of the main glaciation as well as on features of the climate and their variations. Examination of wind directions in southern England since 1723 has revealed that in the period 1780–1850 there was a drop in the frequency of the westerly winds similar to that of recent years, while an examination of the sea surface temperatures has shown over the same early period a similarity with the sea surface temperatures of the last few years; there were also similar wind and pressure anomalies in the region north of the British Isles.

General circulation of the atmosphere

The importance of studies of the general circulation lies not only in the promise they hold for forecasting for long periods ahead but also in relation to the possibility that the world climate may be significantly affected accidentally or deliberately by man's activities. Man's capability for altering the natural environment by changing the nature of the earth's surface and the atmospheric content of certain minor constituents is growing to the extent that measurable effects on the atmospheric circulation cannot be ruled out. On the other hand the natural variations of climate are such that it will certainly be difficult to distinguish any artificially induced changes from those occurring naturally. Thus it is essential that an understanding of the large-scale circulation of the atmosphere should be available so that the possible extent of any modifications may be assessed quantitatively prior to the event.

Another of the major problems occupying the attention of meteorologists is that of deciding for how far ahead it may be possible to predict the weather

with an accuracy that is useful and to determine the network of observations that would be required. The most promising way of attacking such problems of long-range forecasting seems to be by using mathematical methods similar to those used in short-range forecasting and research has continued throughout the year in developing a numerical model of the atmosphere suitable for simulation of atmospheric motion on a global or hemispheric scale over long periods of time. The development up to the end of 1967 was given in some detail in the Special Topic article in the Meteorological Office *Annual Report* for 1967. The computations are extensive and require the whole power of the Science Research Council's Atlas computer for 2 hours to advance the forecast by 24 hours. The main physical effects thought to dominate the long-term development of the motions of the atmosphere have been included in the mathematical description; they are the evaporation and condensation of water accompanied by latent-heat transfer, the effects of radiation and topography and the effects of small-scale motions not treated explicitly in the model, such as friction and turbulent transfer. Before specific prediction experiments can be made it is necessary to establish the dynamic climatology of the model computations and to determine how typical of the real atmosphere are the computed evolutions. Most of the effort during the past year has been directed towards this aim and as a result several changes have been introduced into both the mathematical and the physical aspects of the model.

The computations are carried out at grid points which are 5° of longitude and 3° of latitude apart. Some atmospheric motions are on too small a scale to be represented on this grid and are taken into account in the computations in a statistical way; they are usually referred to as subgrid-scale motions. One of the main problems arises because on this grid the early stages of development of important mid-latitude depressions are poorly represented so that the computations tend to produce fewer and less intense depressions than does the real atmosphere with the same temperature and wind gradients. This problem is crucially related in the computations to the way in which the cumulative effect of subgrid-scale lateral diffusion is introduced and considerable efforts are being devoted to experiments to test the efficacy of various methods of representing this effect, including the use of non-linear diffusion as well as of purely mathematical smoothing operators. Valuable progress has been made with this and other problems and an integration of the model forward in time has now been taken to 35 days. At this stage the results show an encouraging degree of realism and they are being subjected to detailed analysis.

We have continued to receive valuable help from the workers at the Clarendon Laboratory at Oxford in dealing with methods for the computation of radiative transfer in the atmosphere, and Dr R. Shapiro, on an extended visit from the Air Force Research Laboratories, Cambridge, Massachusetts, is collaborating fully with the research group.

Studies of the dynamics of the stratosphere have continued and a three-dimensional mathematical model has been designed for numerical experiments and suitable programmes are being developed and are undergoing preliminary tests. It is hoped that this model, which contains a realistic representation of heating by radiative processes, will produce new information about a variety

of stratospheric problems, such as the mechanisms by which the mean circulation and the large-scale eddies transfer momentum, heat and different 'tracer' substances such as ozone and radioactive material. A pilot investigation has also been made into the use of numerical models for the tracing of trajectories in three dimensions for the study of large-scale diffusion; the results of the 10-level short-range forecasting model were used and the results indicated that the technique is promising.

Charts have been prepared of the mean winds, temperatures and contour heights at the 30-mb level over the northern hemisphere for January and July, in preparation for the publication of mean seasonal charts at this level. The data are being used to compute momentum and heat fluxes for January 1965 and it is intended to extend the computations to provide mean seasonal fluxes.

Storm surges in the North Sea

Throughout the year attention has been paid to the examination and refinement of the empirical formulae used in the prediction of dangerously high tides at east-coast ports, and a set of formulae for use in the provision of early preliminary warnings has been provided. Throughout there has been close collaboration with the Storm Tide Warning Service, the National Institute of Oceanography and the Institute of Coastal Oceanography and Tides (formerly the Liverpool Tidal Institute).

Special investigations

Meteorological advice is frequently sought which cannot be given either from a brief examination of data or from the results of the main lines of research, and as a result a number of special investigations were necessary. Some of these problems called for answers in a short time and a number involved a great deal of investigational work.

An officer visited India in connection with a project sponsored by the Royal Aircraft Establishment, Bedford, to collect data on storm clouds during the pre-monsoon period, and the radar observations at Singapore and Gan are being analysed to give information about the behaviour of cumulonimbus clouds in the tropics. Theoretical and practical investigations have yielded more understanding of clear-air turbulence and have led to proposals for forecasting rules; records of high-level flights over the Rocky Mountains obtained as part of the Royal Aircraft Establishment project have been analysed in relation to turbulence in the stratosphere. The array of anemometers erected last year at Cardington to study wind structure in relation to the landing problems of large aircraft suffered severe damage in a gale and only limited data have been obtained for study; more complete data are expected during the winter 1969/70. An investigation into the effects of meteorological factors on the location of sonic bangs has almost been completed.

Several meteorological reports have been supplied in connection with the choice of a third London Airport, both to the Roskill Commission and to other interested parties, and similar reports for other proposed airports have been called for. Meteorological advice was also given through membership of various departmental and interdepartmental committees.

General Activities of the Research Directorate

A number of members of the staff serve on scientific committees of the Natural Environment Research Council, the Royal Society and other bodies responsible for research in meteorology and related subjects. Close links are thereby maintained with meteorological research in the universities and other organizations. Seven small research projects in universities are directly supported by grants from the Meteorological Office and eight others are assisted through the Gassiot Committee of the Royal Society. Members of university staffs worked in the Meteorological Office as consultants for short periods during university vacations. These arrangements served to maintain a free exchange of knowledge between the Office and the universities.

Mr J. S. Sawyer is acting President of the Commission for Atmospheric Sciences of the World Meteorological Organization. This body is primarily concerned with research aspects of the World Meteorological Organization's activities. Mr Sawyer is also a member of the Joint Organizing Committee for the Global Atmospheric Research Programme which is a major research project to study the world-wide circulation of the atmosphere with satellites and other modern technological devices to which all the scientifically active countries are expected to contribute. Several other members of the Office staff serve on international committees concerned with meteorological research within the World Meteorological Organization or the International Council of Scientific Unions organizations.

A number of research scientists from overseas worked in the Meteorological Office at Bracknell for various extended periods, either supported by their home institutions or by international fellowships; there were four from the United States of America and one from Australia.

The scientific research of the Office was reviewed by the Meteorological Research Committee during the course of eight meetings.

Library and Publications

The National Meteorological Library forms part of the Meteorological Office Headquarters at Bracknell. It is used mainly by staff of the Office but is also available to the professional user from outside the Office and to members of the general public. Almost one-quarter of the loans of publications were to borrowers from outside the Office.

The library provides an exceedingly comprehensive coverage of the literature of meteorology and associated subjects. An indication of the activities of the year is contained in Table XVI on page 65. The number of publications lent (20 470) is higher than ever before, and loans of slides and photographs (for illustration of lectures, books, etc.) have almost doubled over the past two years. Under new purchasing arrangements introduced by Her Majesty's Stationery Office in April, the less expensive publications for the library and the Office must now be obtained directly through a bookseller instead of through HMSO. Some advantages are becoming apparent.

The two translators on the library staff were fully employed and much work was also carried out by freelance translators.

Intake of geomagnetic and seismological literature ceased with the transfer of responsibility in these fields to the Natural Environment Research Council. The arrangements previously in force for the exchange of such literature with 36 foreign institutions were cancelled.

Library staff have continued to participate in the activities of the Association of Special Libraries and Information Bureaux and the Circle of State Librarians. The Office acted as host to the Annual Meeting of the Berkshire Libraries Co-operating Group. Students from Library Schools have been given tuition and opportunities to acquire practical experience.

Meteorological observations in manuscript, and other original documents are kept, in accordance with the Public Records Act of 1958, in special repositories in Bracknell, Edinburgh and Belfast. The material in these Archives is being consulted by an increasing number of users.

The Editing Section is responsible for preparing official publications for printing and it works in close co-operation with HMSO. The official publications are listed in Appendix III and include the *Meteorological Magazine* which provides a valuable medium for the publication of short scientific papers of interest and importance to the scientific staff of the Office in their day-to-day work.

The Cartographic Drawing Office prepares diagrams for Meteorological Office publications, for internal memoranda and for reports in scientific journals of research by Meteorological Office staff. It also prepares for various areas of the world the many charts and diagrams which are used as background maps on which meteorological observations are plotted.

Training

Formal professional training for staff in each of the three scientific classes is provided at the Meteorological Office Training School, Stanmore.

The basic courses for Scientific and Experimental Officers are designed to give a good theoretical background but also to lay particular emphasis on practical aspects of the subject, formal instruction at the School being supplemented by operational experience at Headquarters or outstations. A new feature of these courses is a short series of lectures on management, intended to help these meteorologists with the administrative and staff matters which may concern them at operational units. In addition to these basic courses the School runs a number of specialist and refresher courses, mostly for members of the Experimental Officer grades.

Following a review of the training of the Scientific Officer class emphasis on synoptic meteorology and forecasting has been reduced somewhat and the physical and dynamical meteorological content of the course widened. Some 10 days have been allocated to field work and the class has made several visits to the disused airfield at Bovingdon to investigate wind profiles. All new Scientific Officers spend seven months at the School, but the training period at

outstations has been reduced to one month in the middle of the course. The final month will, in future, include four courses of advanced lectures, two from the field of dynamical meteorology and two from physical meteorology.

New courses for entrants to the Scientific Assistant class were introduced last year. The majority of new entrants are recruited for work at synoptic stations; they are given a four-week Initial Assistants' Course which is mainly in practical work and intended to equip the newcomer for working under supervision at an outstation. Those new entrants who will be employed on non-synoptic work at Headquarters take a four-week course in Basic Meteorology which combines a theoretical background with appropriate practical work. It is intended that Assistants who have taken these courses should return to the School at the age of 20 or 21 after a few years' experience and take an Advanced Assistants' Course.

Training in radiosonde operation is provided at the Meteorological Office Training School at Hemsby. The Initial Course lasts for 9 weeks and the Advanced Course for 4 weeks.

The training of Technicians continued to be by means of a basic course at RAF, Sealand, followed by practical instruction in servicing equipment at the Experimental Site at Easthampstead, but the contents of the courses and the methods of instruction have been critically examined during the year and considerably improved.

The Voluntary Assistance Programme for overseas students introduced last year whereby the United Kingdom offers long-term Fellowships through the WMO continues. One student is now in the second year of his Ph.D. studies at Reading University and has been joined there by eight others—one taking an M.Sc. course and the rest reading for first degrees in meteorology, mathematics and physics. Another student Fellowship is being sponsored at Reading under the Colombo Plan.

These schemes have not affected the arrangements under which other overseas students continue to attend formal courses at the School and to receive on-the-job training mainly at Headquarters.

The releases for part-time study, agreed mostly for Assistants taking mathematics and physics at Technical Colleges, have increased in number and under the new regulations they include more subjects of study. Eight students are taking a B.Sc. sandwich course at the City University. Three Senior Scientific Officers are reading for Ph.D. at Imperial College and one Scientific Officer is doing so at Reading University.

J. S. SAWYER
Director of Research

STATISTICS OF THE RESEARCH DIRECTORATE

TABLE XVI—LIBRARY AND ARCHIVES

Library

Items received, including duplicates but excluding daily weather reports	8 222
Individual books, pamphlets, articles and microfilms classified and catalogued	6 793
Transparencies acquired	573
Publications lent (excluding daily weather reports and internal 48-hour loans)	20 470
New agreements for exchange of publications	3
Total number of exchange agreements	383
Number of pages translated by Library translators	
Russian	3 158
German	219
Hungarian	31
Bulgarian	14
Icelandic	1
Number of pages translated by freelance translators	948
Total	4 371

Archives

Number of loans	1 561

TABLE XVII—TRAINING

The following figures give details of courses completed during 1969 at the Meteorological Office Training Schools at Stanmore, Hemsby and Easthampstead.

	Number of courses	Length of course in weeks	Number of students
Scientific Officers	1	24	13
Initial Forecasting	2	14	48
Advanced Forecasting	5	6	41
Senior Meteorologists	1	3	12
Basic Meteorology	2	4	31
Climatology	1	4	8
Tropical Meteorology	2	3	10
Mediterranean Meteorology	1	3	8
Advanced Instruments	3	2	31
Auxiliary Observers	2	1	30
Voluntary Observers	1	1	20
Special Course USAF	1	1	10
British Antarctic Survey	1	8	6
Basic Assistants	1	4	3
Initial Assistants	12	4	121
Radiosonde (Initial)	5	9	30
Radiosonde (Refresher)	2	5	3
Radiosonde (Advanced)	3	4	6
Technicians	1	14	10
Total			441

Students from the following territories attended courses which terminated during 1969.

	Number of students
British Honduras	1
Burma	1
Cameroon	2
Channel Islands	2
Cyprus	3
East Africa	9
Ethiopia	1
India	1
Iran	1
Kuwait	2
Libya	2
Malaysia	3
Malta	2
Mauritius	2
Nepal	1
Pakistan	3
Switzerland	6
United States of America	10
Students sponsored by British Antarctic Survey	7
Total	59

INTERNATIONAL CO-OPERATION

The Director-General visited the Irish Republic in April for discussions with the Meteorological Service, and to give a lecture at University College, Dublin. In September he made an official visit to the Soviet Union as a guest of the Hydrometeorological Service of the U.S.S.R. On a tour which took him to Moscow, Leningrad, the Caucasus, Middle Asia and Siberia, he saw a broad cross-section of the research and operational activities of a huge service that employs a staff of over 80 000. In May he attended meetings in Geneva of Directors of Meteorological Services from the U.S.A. and several European countries and of WMO's Panel on the Voluntary Assistance Programme.

The 21st Session of the WMO Executive Committee was held in Geneva from 29 May to 12 June. Dr B. J. Mason was accompanied by Mr B. M. Day, Secretary, Meteorological Office, and Mr D. G. Harley, Assistant Director (International and Planning). Mr J. S. Sawyer attended as acting President of the Commission for Atmospheric Sciences, and Mr L. P. Smith as President of the Commission for Agricultural Meteorology. Mr P. J. Meade, Director of Services, attended as Chairman of the Executive Committee Panel of Experts on Meteorological Aspects of Ocean Affairs. Mr D. G. Harley also reported personally to the Committee as Chairman of its Working Group on Antarctic Meteorology. The major topics discussed included the planning and organization of the first GARP Tropical and Global Experiments, the possible expansion of WMO's work in the fields of hydrology and ocean affairs, and the future structure and method of functioning of WMO, especially of the Executive Committee itself. A meeting of Presidents of Technical Commissions of WMO, which Mr J. S. Sawyer and Mr L. P. Smith also attended, preceded this Session.

Mr J. S. Sawyer, Director of Research, attended the Second Session of the WMO/ICSU Joint Organizing Committee for the Global Atmospheric Research Programme (GARP), and a Symposium on the Global Atmospheric Research Programme organized by the American Meteorological Society in Princeton, U.S.A., from 24 to 31 January. He also attended the Third Session of the WMO/ICSU Joint Organizing Committee for GARP in Paris from 20 to 25 October. These sessions were particularly concerned with the planning of the first GARP Tropical and Global Experiments, and the conditions necessary for carrying them out successfully.

Experts from the European Operating States and Prospective Operating States of North Atlantic Ocean Stations met in London on 18 and 19 February. Meteorological Office representation included Mr V. R. Coles, Deputy Director (Forecasting Services), Commander C. E. N. Frankcom, Marine Superintendent and Mr H. Maggs (Met.O.7). A further meeting was held in Amsterdam from 21 to 23 October, when Mr V. R. Coles was accompanied by Captain A. D. White, acting Marine Superintendent.

Dr B. J. Mason, as President of the Royal Meteorological Society, and about 40 members of the staff attended a Joint Meeting of the Royal Meteorological Society, the American Meteorological Society and the Canadian Meteorological Society, which was held in London from 25 to 29 August on 'The Global Circulation of the Atmosphere'.

Two Regional Associations of WMO met during the year. Regional Association VI (Europe) met in Varna, Bulgaria, from 6 to 19 May. Mr J. Harding, Assistant Director (Agriculture and Hydrometeorology) led the U.K. delegation, which included Mr A. A. Worthington, Assistant Director (Telecommunications), Mr R. F. Zobel, Assistant Director (Central Forecasting) and Instructor Lieutenant Commander B. V. Doxat-Pratt, RN, Directorate of Meteorology and Oceanographic Services (Naval). The principal concerns of the meeting were the plan for the regional meteorological telecommunications system, principles for planning the distribution of processed data in Europe, and the relation of meteorology to economic development.

Regional Association I (Africa), of which the U.K. is a member, met in Geneva from 6 to 17 October. Mr G. Needham attended as the U.K. delegate. The main discussions concerned the problems of implementing the World Weather Watch Plan in Africa, the continued need for international aid programmes, meteorology and economic development, and professional training.

Two Technical Commissions of WMO met during the year. The Commission for Instruments and Methods of Observation met in Paris from 15 to 30 September. Dr N. E. Rider, Assistant Director (Instruments and Observations) led the U.K. delegation, which also included Mr L. S. Clarkson and Mr W. R. Sparks from the Meteorological Office and Instructor Lieutenant Commander D. Macdonald, RN, Directorate of Meteorology and Oceanographic Services (Naval). The important topics discussed included instruments and methods of observation on aerodromes, upper air measurements, automatic weather stations, radar meteorology and radiation.

The Commission for Climatology met in Geneva from 18 October to 1 November. The U.K. delegation, led by Mr R. H. Clements, Deputy Director (Observational Services), included Mr J. H. Brazell, Assistant Director (Climatological Services), Mr R. A. S. Ratcliffe, Assistant Director (Synoptic Climatology) and Mr J. M. Craddock. Discussions covered, among other things, proposals for constituting meteorological data libraries at various centres, the economic benefits of climatological work especially for design of structures and for town planning, work on climatic change, and the role of climatology in the study of the human environment.

Other WMO meetings, or joint WMO meetings with other international bodies, in which Meteorological Office staff took part, were as follows:

Subject	*Place and date*	*Attended by*
RA VI (Europe) Working Group on Meteorological Transmissions	Geneva March	Mr A. A. Worthington, Assistant Director (Telecommunications) Mr E. J. Bell (Met.O.5)
EC Panel of Experts on the Structure and Functioning of WMO	Geneva March–April	Mr D. G. Harley, Assistant Director (International and Planning)

Subject	*Place and date*	*Attended by*
EC Working Group on Antarctic Meteorology	Buenos Aires April	Mr D. G. Harley, Assistant Director (International and Planning)
Sixth Air Navigation Conference ICAO/CAeM Extraordinary Session	Montreal April–May	Mr J. K. Bannon, Assistant Director (Public Services) Mr L. Sugden (Met.O.7)
Advisory Committee on Marine Resources Research (FAO)/Scientific Committee on Ocean Research/ WMO Joint Working Party on Scientific Aspects of International Ocean Research	Rome and Ponza, Italy April–May	Mr P. J. Meade, Director of Services
Consultancy on Data Storage and Retrieval	Geneva May	Mr J. M. Craddock (Met.O.13)
CSM Working Group on Data Needs and Codes	Geneva June	Mr R. H. Clements, Deputy Director (Observational Services) Mr N. E. Davis (Met.O.13)
RA VI (Europe) Regional Comparison of National Standard Pyrheliometers	Carpentras, France June	Mr S. G. Crawford (Met.O.14)
Sixth Session of IOC and EC Panel Working Group Discussion on Ocean Observing Systems	Paris September	Mr P. J. Meade, Director of Services
Technical Conference on Upper Air Instruments and Observations	Paris September	Dr N. E. Rider, Assistant Director (Instruments and Observations) Mr A. H. Hooper (Met.O.16)
Meetings of CSM Working Group on Telecommunications Study Group on Digital Facsimile	Paris and Geneva September	Mr C. E. Goodison (Met.O.5)
CAgM Working Group on Agrometeorological Aspects of Micrometeorology	Geneva September	Mr L. P. Smith (Met.O.8)
EC Panel of Experts for the International Hydrological Decade	Geneva September	Mr J. Harding, Assistant Director (Agriculture and Hydrometeorology)
CHy Advisory Working Group	Geneva September	Mr J. Harding, Assistant Director (Agriculture and Hydrometeorology)
Informal Planning Meeting on the Scope and Goals of the WWW Plan 1972–75, and on development of WWW Satellite Sub-System	Geneva September–October	Mr P. J. Meade, Director of Services Mr M. J. Blackwell (Met.O.16)
Informal meeting of experts to analyse requirements for facsimile processed data	Geneva September–October	Mr R. F. Zobel, Assistant Director (Central Forecasting)
CSM Working Group on Telecommunications	Rome November	Mr A. A. Worthington, Assistant Director (Telecommunications) Mr E. J. Bell (Met.O.5)
International Conference on Practical and Scientific Results of the International Hydrological Decade and on International Co-operation in Hydrology (UNESCO/WMO)	Paris December	Mr J. Harding, Assistant Director (Agriculture and Hydrometeorology) Mr A. Bleasdale (Met.O.8)

Attendances, not already listed, at international conferences sponsored wholly or primarily by bodies other than WMO, and other visits abroad were as follows:

Subject	*Place and date*	*Attended by*
Iceland/Republic of Ireland/Netherlands/U.K. Working Group on Telecommunications	De Bilt, The Netherlands January	Mr A. A. Worthington, Assistant Director (Telecommunications) Mr E. J. Bell (Met.O.5)
Inspection visit of Meteorological Offices	Persian Gulf January	Mr V. R. Coles, Deputy Director (Forecasting Services)
Visits to Instrumental Research Centres in U.S.A.	Boston, Fort Monmouth January–February	Mr W. R. Sparks (Met.O.16)
Visits to establishments in U.S.A. and attendance at American Meteorological Society Symposium on Meteorological Observations and Instrumentation	U.S.A. January–February	Dr N. E. Rider, Assistant Director (Instruments and Observations) Mr W. R. Sparks (Met.O.16)
Atlantic Trade Wind Expedition (at sea)	Gibraltar–Freetown January–February	Mr N. Thompson and Mr F. R. Mott (Met.O.14)
Meeting to discuss meteorological telecommunications arrangements for the Washington–Bracknell–Paris–Offenbach Main Trunk Circuits	Paris February	Mr A. A. Worthington, Assistant Director (Telecommunications) Mr E. J. Bell (Met.O.5)
Visit to French Meteorological Service in connection with the establishment of a radiosonde station in the New Hebrides	Paris February–March	Mr M. R. Robson (Met.O.16) Mr G. Needham (Met.O.17)
Hydrometeorological studies	Thailand February	Mr J. S. Hopkins (Met.O.8)
Conference 'Oceanology International '69'	Brighton February	Dr J. D. Woods (Met.O.14)
Discussions on research into clear-air turbulence	U.S.A. and Canada February–April	Mr J. M. Nicholls (Met.O.9)
Discussions on Air–Sea Interaction problems (also as visiting Professor in the Institute of Atmospheric Science)	Miami March–May	Dr J. D. Woods (Met.O.14)
Final preparation of molecular oxygen experiment launched on SKYLARK rocket	WRE, Salisbury, Rocket Range, Woomera, University of Adelaide March–May	Mr M. J. Kerley (Met.O.19)
Specification meeting for ESRO rocket payload S61	Munich April	Dr P. Ryder, Mr G. P. Carruthers and Mr D. E. Miller (Met.O.19)
On-site discussion about proposed radiosonde station	New Hebrides April	Mr G. Needham (Met.O.17)
Meeting on Fluid Mechanics in relation to Natural Phenomena	Newcastle-on-Tyne April	Mr E. Knighting, Deputy Director (Dynamical Research)
Visits to Meteorological Services in connection with measurements of high storm tops	New Delhi, Calcutta, Singapore, Gan April–May	Mr S. G. Cornford (Met.O.9)

Subject	*Place and date*	*Attended by*
Installation of weather radar for Ministry of Overseas Development	Turkey April–June	Mr P. Bradley and Mr J. Somers (Met.O.16)
Meeting for technical discussions on experiment for ESRO payload S61	Munich May	Dr P. Ryder and Mr A. Bentley (Met.O.19)
COSPAR XIIth Plenary Meeting	Prague May	Dr R. Frith, Deputy Director (Physical Research) Mr E. Knighting, Deputy Director (Dynamical Research)
Annual meeting of the Advisory Committee of European Operating States on North Atlantic Ocean Stations	Stockholm May	Commander C. E. N. Frankcom (Marine Superintendent)
Meeting to discuss meteorological arrangements in connection with the weather ship in the North Sea	Oslo May	Mr R. K. Pilsbury (Met.O.5)
Meeting of NATO Panel on Advanced Telecommunications	Brussels May	Mr A. A. Worthington, Assistant Director (Telecommunications)
To work at the National Environmental Satellite Center, ESSA, on the first data from the infra-red temperature recorder on NIMBUS 3 launched April 1969	Suitland, Maryland, U.S.A. May–June	Dr D. G. James (Met.O.15)
Seventh Meeting of the Commonwealth Air Transport Council	London June	Mr M. H. Freeman and Mr L. Sugden (Met.O.7)
Hydrometeorological studies	Iran June	Mr J. S. Hopkins (Met.O.8)
Colloquium on the Spectra of Meteorological Variables	Stockholm June	Dr J. D. Woods and Dr C. J. Readings (Met.O.14)
Attachment to European Space Technology Centre to assist in writing the meteorological specification for the proposed European Meteorological Operational Satellite	Noordwijk, The Netherlands June–July	Dr D. G. James (Met.O.15)
Visit to the Watermanship Training Centre, BAOR, to advise on wind and current measurements required in connection with the 1972 Olympic sailing events	Kiel July	Mr D. M. Houghton (Met.O.2)
British Interplanetary Society International Summer School on Earth Observation Satellites	Cambridge July	Mr D. E. Miller (Met.O.19)
Commission II of 16th General Assembly International Scientific Radio Union (URSI)	Ottawa August	Dr W. T. Roach (Met.O.9)
Fifth International Biometeorological Congress	Montreux August–September	Dr R. W. Gloyne and Mr G. W. Hurst (Met.O.8) Mr N. C. Helliwell (Met.O.3)
Final preparation of ozone experiment on BLACK BRANT rocket	Fort Churchill, Ottawa, Saskatoon August–September	Dr P. Ryder (Met.O.19)
International Association for Quaternary Research	Paris August–September	Mr H. H. Lamb (Met.O.13)
ESRO Sub-Group 'Meteorological Instrumentation and Operations'	Noordwijk, The Netherlands September	Dr R. Frith, Deputy Director (Physical Research)

Subject	*Place and date*	*Attended by*
Commission on Atmospheric Chemistry and Radioactivity—Symposium on Atmospheric Trace Constituents and Atmospheric Circulation	Heidelberg September	Mr R. A. Hamilton, Assistant Director (High Atmosphere) Mr P. Goldsmith, Assistant Director (Cloud Physics) Dr R. J. Murgatroyd (Met.O.20)
International Statistical Organization Meeting	London September	Mr J. M. Craddock (Met.O.13)
NATO Advisory Group for Aero-Space Research and Development Fluid Dynamics Panel 'The Aero-Dynamics of Atmosphere Shear Flow'	Munich September	Dr W. T. Roach (Met.O.9) Dr F. B. Smith (Met.O.14)
IUGG Meeting	Madrid September	Dr R. Hide, Head of Met.O.21
Meeting of U.K./Iceland Meteorological Telecommunications Working Group	Reykjavik September	Mr. A. A. Worthington, Assistant Director (Telecommunications) Mr E. J. Bell (Met.O.5)
Visit at the request of the Board of Trade to the Deutscher Wetterdienst	Offenbach September	Mr L. Sugden (Met.O.7)
International Council for Exploration of the Sea, Symposium on Physical Variability in the North Atlantic	Dublin September	Mr H. H. Lamb (Met.O.13) Dr J. D. Woods (Met.O.14)
International Biological Symposium 'Man-made changes in the environment'	London September	Mr L. P. Smith and Mr C. V. Smith (Met.O.8)
Conference on Condensation and Ice Nuclei	Prague and Vienna September	Mrs C. M. Stevenson (Met.O.15)
Meeting to discuss meteorological telecommunication arrangements for the Washington/Bracknell/Paris/Offenbach Main Trunk Circuits	Offenbach September–October	Mr A. A. Worthington, Assistant Director (Telecommunications) Mr E. J. Bell (Met.O.5)
NATO Visiting Lectureship	Canada and U.S.A. September–October	Mr F. H. Bushby, Assistant Director (Forecasting Research)
Meetings to discuss meteorological telecommunication arrangements for high-speed circuit Bracknell/Offenbach	Offenbach October	Mr A. A. Worthington, Assistant Director (Telecommunications) Mr E. J. Bell (Met.O.5)
International Symposium on Visibility and Air Pollution	London October	Mr L. S. Clarkson (Met.O.16)
Liaison visit to Data Handling Division CERN (European Organization for Nuclear Research)	Geneva October	Mr N. Bradbury, Assistant Director (Data Processing) Mr G. Howkins (Met.O.12)
Installation of weather radars for Ministry of Overseas Development	Turkey, Iran October–December	Mr P. Bradley (Met.O.16)
Consultation with Defence Ministry of Federal Republic of Germany	Bonn October	Mr H. H. Lamb (Met.O.13)
Seminar on causes and prospects of climate change	Bonn and Cologne October	Mr H. H. Lamb (Met.O.13)
First stage of collaboration with the Boundary Layer Branch of Air Force Cambridge Research Laboratories on joint atmospheric turbulence studies in 1970 and 1971	Boston October	Dr C. J. Readings and Mr H. E. Butler (Met.O.14)

Subject	*Place and date*	*Attended by*
WRE Salisbury and Woomera Rocket Range with visits to University of Adelaide for launch of SKYLARK SL 801	Salisbury, Woomera, Australia October–December	Mr M. J. Kerley (Met.O.19)
Symposium on Multiple Source Urban Diffusion Models; arranged by the National Air Pollution Control Administration	Chapel Hill, N. Carolina October	Dr F. Pasquill (Met.O.14)
Discussions with ESSA groups concerned with turbulence and diffusion	U.S.A. October–November	Dr F. Pasquill (Met.O.14)
Visit to site of proposed upper air station	Tarawa November	Mr G. Needham (Met.O.17)
South Pacific Air Transport Council—19th Session	Fiji November	Mr G. Needham (Met.O.17)
Visit to Hawaii University	Honolulu November	Mr G. Needham (Met.O.17)
Accademia Nazionale dei Lincei—International Meeting on Floods—their prediction and the defence of the soil	Rome November	Mr G. R. R. Benwell (Met.O.11)
NATO Advisory Group on Meteorology	Brussels November	Mr J. S. Sawyer, Director of Research
Inspection visit of Meteorological Offices	Singapore November	Mr V. R. Coles, Deputy Director (Forecasting Services)
Visit as official British Exchange Representative to U.S.A. Antarctic Expedition stations	Antarctica November	Mr D. G. Harley, Assistant Director (International and Planning)
Discussions with national meteorological services	Washington, U.S.A. and Wellington, N.Z. November	Mr D. G. Harley, Assistant Director (International and Planning)
International Hydrological Decade—5th Session of the Co-ordinating Council	Paris December	Mr J. Harding, Assistant Director (Agriculture and Hydrometeorology)

The following members of the staff were released during the year to take up international appointments overseas:

Mr R. F. Johnson	Experimental Officer	Seconded in January to British Antarctic Survey, Falkland Islands
Mr P. F. McAllen	Senior Experimental Officer	Seconded in January to Ministry of Overseas Development for service in the Caribbean
Mr P. F. Emery	Senior Experimental Officer	Seconded in February to Board of Trade for service at the South Pacific Air Transport Council's meteorological station at Nandi, Fiji
Mr F. D. Wilmot	Experimental Officer	Seconded in June to Ministry of Overseas Development for service in the Bahamas
Mr J. Fleming	Chief Experimental Officer	Released in June on special leave to SHAPE, Belgium
Mr L. S. Birch	Senior Experimental Officer	Seconded in July to Ministry of Overseas Development for service in the Bahamas
Miss I. K. C. Carter	Senior Scientific Assistant	Released in July to WMO Secretariat, Geneva
Mr F. V. Reed	Experimental Officer	Released in August to WMO Secretariat, Geneva
Mr T. O'Byrne	Senior Scientific Assistant	Released in September for service with Australian Meteorological Bureau
Mr D. G. Ward	Experimental Officer	Seconded in December to Ministry of Overseas Development for service in Antigua

The following staff returned to the Office from appointments overseas:

Mr J. D. Lowry	Senior Scientific Assistant	From Malawi, in February
Mr C. F. Neave	Senior Experimental Officer	From East Africa, in March
Mr P. G. Rackliff	Senior Experimental Officer	From Nandi, Fiji (SPATC), in March
Mr A. C. Wall	Senior Experimental Officer	From East Africa, in June
Mr A. Blackie	Senior Experimental Officer	From British Antarctic Survey, Falkland Islands, in June
Mr A. Ward	Chief Experimental Officer	From SHAPE, Belgium, in July
Mr A. F. Jenkinson	Principal Scientific Officer	From Nairobi, in October
Mr C. E. Wallington	Principal Scientific Officer	From CSIRO, Australia, in October
Mr R. Frost	Senior Principal Scientific Officer (now retired)	From Zambia, in December

STAFF

GENERAL

The names of the principal officers of the Meteorological Office are listed on pages xii–xiii and the organization of the Office is shown in the diagram on page xiv. At the end of 1969 the total number of posts of all grades was 3777, an increase of 81 over the year. The actual strength at the end of the year, including Research Fellows, was made up as follows:

Scientific Officer Class		
Chief Scientific Officers	3	
Deputy Chief Scientific Officers	6	
Senior Principal Scientific Officers	26	
Principal Scientific Officers	72	
Principal Research Fellows	2	
Senior Scientific Officers	41	
Scientific Officers	25	
Administrative Class		
Assistant Secretary	1	
Principal	1	
Experimental Officer Class		
Chief Experimental Officers	33	
Senior Experimental Officers	238	
Experimental Officers	443	
Assistant Experimental Officers	178	
Scientific Assistant Class		
Senior Scientific Assistants	337	+
Scientific Assistants	1089	-
Marine Staff		
Marine Superintendent	1	
Nautical Officer Class	9	
Ocean Weather Ships and Base		
Officers	92	
Crew	110	
Technical and Signals Grades	290	+9
Executive and Clerical Grades	184	—
Typing and miscellaneous non-industrial grades	154	-8
Industrial employees	82	-10
Locally entered staff and employees overseas	183	+6

Recruitment into the Scientific Officer class during 1969 continued at the high level set in the previous two years with 10 new entrants. The overall manning position in the Experimental Officer class has been satisfactory throughout the year and recruitment has therefore been relatively light. As in previous years, the main problem facing the Office lay in the recruitment and retention of Scientific Assistants. With a higher than usual intake during 1969 and a somewhat lower wastage rate it has been possible to reduce the shortfall considerably but despite this the position is still not satisfactory. There has been full manning in the Technician field throughout the year and it has been possible to recruit a small surplus against known future needs.

The Office has continued its sponsorship of three Senior Scientific Officers who are working towards Ph.D. degrees under a scheme organized in conjunction with Imperial College, London University, and, in addition, one Scientific Officer is being similarly supported in his attempt to obtain a Ph.D. degree at Reading University. One Scientific Officer, four Experimental Officers, nine Assistant Experimental Officers and one Telecommunications Technical Officer have been allowed Sandwich Courses or full-time study release to proceed towards degrees. One Assistant Experimental Officer has been awarded a Civil Service Department Bursary to carry out degree studies at the Royal Military College of Science, Shrivenham. During the year five college-based Sandwich Course students spent their extra-college periods working in the Office. Study concessions at various levels were enjoyed by 263 members of the staff and out of 150 applicants, 27 university undergraduates were chosen to work in the Office as students during the long vacation. Two 'vacation consultants' from universities contributed to the work of the Office during the year.

CHANGES IN SENIOR STAFF

Mr E. Evans, M.Sc., succeeded Mr S. E. Virgo, O.B.E., M.Sc., as Chief Meteorological Officer at Headquarters, Strike Command, RAF.

Captain G. A. White succeeded Commander C. E. N. Frankcom, O.B.E., R.D., as Marine Superintendent.

Mr D. Hanson, M.A., succeeded Mr B. M. Day, B.Sc.(Econ.), as Secretary of the Meteorological Office.

HONOURS AND DISTINCTIONS

Mr A. J. Willis was awarded the O.B.E. and Mr D. F. MacGregor the M.B.E.

Dr R. Hide received the Doctor of Science degree from Cambridge University.

The L. G. Groves Memorial Prize for Meteorology was awarded to Dr K. A. Browning and Mr B. R. Kerley received the Meteorological Observer's Award.

APPENDIX I

BOOKS OR PAPERS BY MEMBERS OF THE STAFF

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VIRGO, S. E., *see* STEELE, L. P., STROUD, P. A. J. and VIRGO, S. E.

WALTERS, E. V.; Wet Thursdays? *Weather, London,* **24,** 1969, pp. 415–416.

WEBSTER, F. B.; A short investigation into the relationship between the duration of sunshine and total cloud amount. *Met. Mag., London,* **98,** 1969, pp. 87–92.

WILDMAN, P. J. L., Ph.D., KERLEY, M. J. and SHAW, M. S., B.A.; Molecular oxygen measurements from 100 to 150 km at Woomera, Australia. *Jnl atmos. terr. Phys., London,* **31,** 1969, pp. 951–957.

WILDMAN, P. J. L., *see* MILLER, D. E., STEWART, K. H. and WILDMAN, P. J. L.

WILDMAN, P. J. L., *see* STEWART, K. H. and WILDMAN, P. J. L. with SMITH, F. G. *et alii.*

WOODROFFE, A., B.Sc.; A weather routeing service for shipping. *Shipping, Liverpool,* **58,** 1969, No. 2, pp. 20–22.

WOODS, J. D., Ph.D., D.I.C.; Diurnal behaviour of the summer thermocline off Malta. *Dt. hydrogr. Z., Hamburg,* **21,** 1968, pp. 106–108.

WOODS, J. D., Ph.D., D.I.C.; Introduction to turbulence in stratified flow (pp. 39–51). Micro-oceanographical work off Malta (pp. 52–56). Turbulence and the transition from laminar to turbulent flow in stratified fluids (pp. 57–66). Clear air turbulence and its relations to turbulence in the sea (pp. 67–73). Université de Liège. Hydrodynamique de l'Océan, Liège, 1969. (Proceedings of a colloquium held in May 1969 at the Université de Liège).

WOODS, J. D., Ph.D., D.I.C.; On designing a probe to measure ocean microstructure. *Underwater Sci. Tech. Jnl, London,* **1,** 1969, pp. 6–12.

WOODS, J. D., *see* HOUGHTON, D. M. and WOODS, J. D.

WRIGHT, P. B., B.Sc.; Effects of wind and precipitation on the spread of foot-and-mouth disease. *Weather, London,* **24,** 1969, pp. 204–213.

WRIGHT, P. B., *see* DE LA MOTHE, P. D. and WRIGHT, P. B.

YOUNG, W. K.; The Shelton regulator clock at Edinburgh Meteorological Office. *Met. Mag., London,* **98,** 1969, pp. 370–373.

ZOBEL, R. F., O.B.E., B.Sc.; The meteorology of weather routeing. *Mar. Obsr, London,* **39,** 1969, p. 26.

APPENDIX II

A SELECTION OF THE LECTURES AND BROADCASTS GIVEN BY MEMBERS OF THE STAFF

BARTLETT, J. T., Ph.D.
Controlling the weather. *Nicholas Society, Slough.* 22 October.

BENWELL, G. R. R., M.A.
Evidence of fronts in forecasts produced from a 10-level model. *Conference at Reading University on Fronts in the Atmosphere and Ocean.* 13 May.
Numerical weather prediction using a 10-level atmospheric model. *Symposium on Computer Science, Girton College, Cambridge.* 8–11 August.
Numerical studies of frontal behaviour using a 10-level primitive equation model. *AMS/RMS Joint Meeting on the Global Circulation of the Atmosphere, London.* 25–29 August.

BLEASDALE, A., B.A., B.Sc.
Requirements for rainfall and evaporation data *and* Processing of meteorological data in the Meteorological Office. *Water Resources Board Conference, Reading.* 7–8 January.
Rainfall of mid-September 1968 in comparison with previous exceptional rainfall in the United Kingdom. *Water Engineers' Conference, Cranfield.* 17 July.
Accuracy of rainfall measurements. *Radio and Space Research Station, Slough.* 23 July.

BORRETT, P. D., B.Sc.
Modern meteorology. *Royal Masonic Senior School, Bushey.* 6 February.
Course of 10 lectures on elementary meteorology. *Rickmansworth Evening Institute.* February–May.

BROWNING, K. A., Ph.D., D.I.C.
Richardson number limited shear zones in the free atmosphere. *Reading University.* 13 May.
Frontal structure in the mesoscale. *AMS/RMS Joint Meeting on the Global Circulation of the Atmosphere, London.* 28 August.

BRYANT, K.
Effects of weather and terrain on radioactive fall-out. *Rome Office (Sector Scientists) Conference, Civil Defence School, Easingwold.* 17 September.

BUSHBY, F. H., B.Sc.
An atmospheric model suitable for rainfall prediction. *Applied Mathematics Seminar, Exeter University.* 7 March.
Recent results with a 10-level model suitable for detailed weather prediction. NATO Visiting Lectureship to Canada and U.S.A.:
Canadian Meteorological Society, McGill University, Montreal. 30 September.
Central Analysis Office, Montreal. 1 October.
Cambridge Air Force Research Laboratories, Bedford, Massachusetts. 7 October.
Massachusetts Institute of Technology, Cambridge, Massachusetts. 10 October.
Princeton University, New Jersey. 13 October.
Environmental Science Services Administration, National Weather Center, Washington. 17 October.
National Center for Atmospheric Research, Boulder, Colorado. 22 October.
Headquarters, Meteorological Service of Canada, Toronto. 24 October.

CORBY, G. A., B.Sc.
The general circulation of the atmosphere. *National Institute of Oceanography, Wormley, Surrey.* 21 January.

CRADDOCK, J. M., M.A.

The application of eigenvector analysis to 500-mb fields. *Humber Group of the Royal Statistical Society, Hull.* 27 January.

Statistics and weather forecasting.
Highlands Group of the Royal Statistical Society, Aberdeen. 14 April.
Mathematics Seminar of the University of Bradford. 21 May.

Some meteorological applications of principal component analysis.
Birmingham Group of the Royal Statistical Society. 6 November.
Leeds/Bradford Group of the Royal Statistical Society. 13 November.

Recent work on eigenvector analysis. *Imperial College, London.* 2 December.

CROSSLEY, A. F., M.A.

Atmospheric environment of supersonic aircraft. *Royal Meteorological Society, London.* 18 June.

ELSE, C. V.

Electronics in meteorological instrumentation. *South-western Section of the Society of Electronic and Radio Technicians (SERT), Bristol.* 16 October.

FRITH, R., O.B.E., Ph.D.

The atmosphere of the earth. *Royal Society of Arts, London.* 6 January.

Satellite meteorology (AGARD lecture series).
Kurhaus, Aachen. 28 October.
Reading University. 31 October.
Ottawa. 3 November.

Potential value of satellites in meteorology. *Southampton University.* 12 November.

The upper atmosphere. *University College of Swansea.* 26 November.

GADD, A. J., Ph.D.

The representation of subgrid-scale convection in numerical weather prediction models. *Conference on Computational Physics, Culham Laboratory, Abingdon.* 28–31 July.

The representation in a 10-level model atmosphere of sensible and latent-heat transfer from the earth's surface to the atmospheric boundary layer. *AMS/RMS Joint Meeting on the Global Circulation of the Atmosphere, London.* 25–29 August.

GILCHRIST, A., M.A.

Some of the problems arising in general circulation work in the Meteorological Office. *Institute of Physics and the Physical Society, Culham Laboratory, Abingdon.* 29 July.

GLOYNE, R. W., Ph.D.

Biometeorology (2 lectures). *Geography honours students, Edinburgh University.* 14 and 21 January.

GOLDSMITH, P., M.A.

Project Scillonia.
Reading University. 13 May.
Clarendon Laboratory, Oxford. 12 June.

The role of direct condensation on the scavenging of particulates from the atmosphere. *International Conference on Atmospheric Chemistry and Radioactivity, Heidelberg Castle.* 10 September.

Dealing with hurricanes. *BBC Radio 4 sound broadcast.* 19 August.

GRANT, D. R., B.Sc.

Meteorological measurements in a field of barley. *Pure and applied plant physiology groups, Nuffield Foundation, Cambridge.* 12 June.

HEASTIE, H., M.Sc.

Meteorological physics. *Cavendish Laboratory, Cambridge.* 24 March.

HELLIWELL, N. C., B.Sc.

Climatology. *Course on Thermal Environment, Institute of Advanced Architectural Studies, York.* 2–6 June.

Extreme wind speeds for building design. *Brixton School of Building, London.* 18 November.

HIDE, R., D.Sc.

Magnetohydrodynamic oscillations of the earth's core in relation to the theory of the Chandlerian nutation. *Royal Astronomical Society, London.* 24 January.

Dynamics and magnetohydrodynamics of the earth's deep interior. *Cambridge University.* 5 February.

Magnetohydrodynamics of rotating fluids and the earth's magnetism. *Department of Mathematics, Exeter University.* 14 February.

Magnetohydrodynamics of rotating fluids. *Conference on Fluid Dynamics in relation to Natural Phenomena. Institute of Physics, Newcastle.* 16 April.

Baroclinic waves in a fluid subject to internal heating. (With P. J. Mason.) *Conference on Fluid Dynamics in relation to Natural Phenomena, Institute of Physics, Newcastle.* 18 April.

Dynamics of the atmosphere of the major planets. *Conference on the Major Planets, Kitt Peak National Observatory, Tucson, Arizona.* 2 May.

Rotating fluids. *European Space Research Institute, Frascati.* 27 June.

Planetary atmospheres. *European Space Research Organization Summer School, Interlaken.* 19 August.

Laboratory experiments on thermal convection in a rotating fluid in relation to the theory of the global circulation of the atmosphere. *AMS/RMS Joint Meeting on the Global Circulation of the Atmosphere, London.* 29 August.

Novel correlations between global features of the earth's gravitational and magnetic fields. *IAGA Symposium on Geomagnetic Secular Change, Madrid.* 2 September.

Dynamics and magnetohydrodynamics of rotating fluids. *NATO Summer School, Bangor, North Wales.* 16–18 September.

Dynamics of the earth's deep interior. *Department of Geophysics, Reading University.* 21 November.

HOGG, W. H., M.Sc.

Climatic factors in apple growing. *Conference on Apple Growing, Wisbech.* 2 January.

Weather and plant diseases with particular reference to spore transport. *Royal Meteorological Society meeting, Bristol.* 15 January.

The estimation of long-term irrigation needs. *Symposium on the Role of Water in Agriculture, Aberystwyth.* 19 March.

Regional and local environments. *Symposium on Potential Crop Production, Aberystwyth.* 8 July.

Weather, climate and plant disease. *British Association Annual Meeting, Exeter.* 10 September.

HOOPER, A. H.

Problems of automatic computation of radiosonde data *and* Some features of the new United Kingdom Radiosonde Mk 3. *WMO Technical Conference on Upper Air Instrumentation, Paris.* 10 September.

HURST, G. W., B.Sc., D.I.C.

External protection of plants against meteorological extremes. *Fifth International Biometeorological Congress, Montreux.* 2 September.

Summer temperatures and honey production. *Joint Conference of Country Beekeeping Instructors and NAAS Beekeeping Advisers, London.* 13 November.

Trajectories from the continent to Great Britain. *British Ecological Society, London.* 4 December.

JAMES, D. G., Ph.D.

A technique for direct measurement of divergence in the atmosphere. *ESSA, National Environmental Satellite Center, Suitland.* 3 June.

Some preliminary results of the infra-red temperature sounder on NIMBUS 3. *AMS/RMS Joint Meeting on the Global Circulation of the Atmosphere, London.* 29 August.

The possible effects of cloud seeding on rainfall. *BBC Radio 4 sound broadcast 'New Worlds'.* 11 April.

JOHNSON, D. H., M.Sc.

The role of the tropics in the global circulation. *AMS/RMS Joint Meeting on the Global Circulation of the Atmosphere, London.* 27 August.

LAMB, H. H., M.A.

Principles of climate and development of the climatic sequence. *Course of 8 lectures, Polar Research Institute, Cambridge University.* 17 January to 7 March.

The climatic sequence of the last ice age and since, a meteorological analysis. *Natural History Museum, London.* 19 March.

Volcanic activity and climate. *Eighth Congress of INQUA, Paris.* 2 September.

Atmospheric circulation during the last ice age. *Eighth Congress of INQUA, Paris.* 3 September.

Our ever-changing climate. *Annual Conference of the Botanical Society of the British Isles, London.* 19 September.

The magnitude of climatic anomalies and some related features of the atmospheric circulation. *ICES Symposium, Dublin.* 26 September.

Climate and history now and in the past. *Cambridge College of Arts and Technology.* 9 October.

The problem of future climate trends and climate forecasting. *Meteorological Departments of the University of Bonn and the University of Köln, Bonn.* 16 October.

Climate and history. *Norfolk branch of the Geographical Association, Norwich.* 10 November.

Contribution to BBC 1 television programme 'London This Week'. 3 November.

MASON, B. J., D.Sc., F.R.S.

Weather forecasting in the satellite and computer age.
Rutherford Laboratory, Didcot. 9 January.
British Association, Southampton University. 25 March.
No. 19 Group, Royal Air Force, Plymouth. 26 March.
Institute of Physics and the Physical Society, Queen's University, Belfast. 24 April.
Institute of Physics, University College, Dublin. 25 April.
Oxford Young Scientists' Branch, British Association, Inaugural Lecture. 16 May.
National Physical Laboratory, Teddington. 16 June.
British Association Annual Meeting, Exeter, Young People's Programme. 4 September.
RRE Lecture Society, Royal Radar Establishment, Gt Malvern. 8 October.
Midlands Branch of the Institute of Physics, Lanchester College, Coventry. 9 October.
Physical Society, Sheffield University. 21 October.
West Yorkshire Branch, British Association, Bradford. 22 October.
General Lectures Programme, Durham University. 6 November.
U.K. Atomic Energy Authority, Aldermaston. 13 November.

The physics of the thunderstorm. *Queen Elizabeth College, London.* 11 March.

Some outstanding problems in cloud physics—the interaction of micro-physical and dynamical processes.
Royal Meteorological Society, London, Presidential Address. 16 April.
Scottish Centre, Royal Meteorological Society, Edinburgh. 7 November.

Observing the weather from satellites. *British Association Science Fair, Portsmouth.* 8 July.

Numerical weather prediction. *Conference on Computational Physics, Culham Laboratory, Abingdon.* 29 July.

The scientific problems of rainmaking. *International Association for Statistics in Physical Sciences, London School of Hygiene.* 11 September.

MASON, P. J., B.Sc.

Baroclinic waves in a fluid subject to internal heating. (With R. Hide.) *Conference on Fluid Dynamics in relation to Natural Phenomena, Institute of Physics, Newcastle.* 18 April.

MILLER, D. E., B.A.

The measurement of ozone from a satellite. *International Summer School of the British Interplanetary Society on Earth Observation Satellites, Cambridge.* 17 July.

MURGATROYD, R. J., O.B.E., Ph.D., C.Eng., M.I.E.E.

The structure and dynamics of the lower stratosphere. *AMS/RMS Joint Meeting on the Global Circulation of the Atmosphere, London.* 28 August.

MURRAY, R., M.A.

Sea temperature anomalies and long-range forecasting. (With R. A. S. Ratcliffe.) *Royal Meteorological Society, London.* 19 November.

NICHOLLS, J. M., B.Sc.
Lee-waves and turbulence measurements in the stratosphere over mountainous terrain in U.S.A. *Albuquerque Chapter of the American Meteorological Society, Albuquerque, New Mexico.* 9 April.

OWEN, W., M.Sc.
Meteorological services for transport. *Institute of Transport (Western Section), Bristol.* 28 March.

PASQUILL, F., D.Sc.
Turbulent transfer in the planetary boundary layer—the background to the current programme in the Meteorological Office. *Natural Environment Research Council Discussion Meeting on Meteorological Research in United Kingdom, London.* 28 January.
The prediction of diffusion over an urban area—current practice and future prospects. *Symposium on Multiple Source Urban Diffusion Models, University of North Carolina, U.S.A.* 27–30 October.
Department of Geophysics, Reading University. 14 November.

RATCLIFFE, R. A. S., M.A.
Long-range forecasting. *BBC sound broadcast for Radio* 4 (*Manchester*). 18 January. *Interview on long-range forecasting for BBC Radio* 4. 15 March.
Sea temperature anomalies and long-range forecasting. (With R. Murray.) *Royal Meteorological Society, London.* 19 November.

RIDER, N. E., D.Sc.
Simple, inexpensive, reliable instruments for remote land area use. *American Meteorological Society Symposium, Washington, D.C.* 14 February.
The measurement and improvement of radiosonde performance with special reference to the new United Kingdom sounding system. *WMO Technical Conference on Upper Air Instrumentation, Paris.* 10 September.

ROACH, W. T., Ph.D., D.I.C.
The forecasting and remote detection of atmospheric turbulence. *Institute of Electronic and Radio Engineers, London.* 6 March.
Weather and Concorde. *Royal Meteorological Society Sixth Form Lectures, London.* 30 and 31 October.

ROWNTREE, P. R., B.A.
Effects of the distribution of tropical heat sources on the extra-tropical circulation. *AMS/RMS Joint Meeting on the Global Circulation of the Atmosphere, London.* 25 August.

SAWYER, J. S., M.A., F.R.S.
Large-scale disturbances of the equatorial atmosphere. *Symposium on the Global Atmospheric Research Programme, Princeton, New Jersey.* 24 January.
Modern developments in meteorology and weather forecasting. *Institute of Measurement and Control, Loughborough.* 15 May.

SMITH, C. V., M.A., B.Sc.
Animal husbandry and the meteorologist. *Institute of Animal Physiology, Cambridge.* 12 May.

SMITH, F. B., Ph.D.
The rise of hot plumes. *Matlock College of Education.* 1 May.
A review of the vertical transfer of momentum through the boundary layer. *NATO/AGARD Fluid Dynamics Panel on the Aerodynamics of Atmospheric Shear Flows, Munich.* 15–17 September.

SPARKS, W. R.
Current concepts of temperature measurement applicable to synoptic networks. *Symposium on Meteorological Observation and Instrumentation, Washington, D.C.* 11 February.

STEVENSON, CATHERINE M., B.A.
Summary of the measurements of ice nucleus concentrations during January and February 1969. *WMO Sub-committee on Nucleation, Hradec Králové, Czechoslovakia.* 17 September.

THOMPSON, N., B.Sc.
Turbulence measurements over the sea. *Royal Meteorological Society Summer Meeting, Cardiff.* 17 July.

TINNEY, E. B., B.Sc.
Weather forecasting and its application to construction engineering. *Institution of Civil Engineers, Exeter.* 10 January.

WILLIS, A. J.
Weather forecasting. *Engineering Society, Peterborough.* 13 November.

WOODS, J. D., Ph.D., D.I.C.
Observations of mixing in a thermocline. *Royal Astronomical Society, London.* 28 February.
Mixing in the summer thermocline.
Department of Oceanography, Nova University, Fort Lauderdale, Florida. 26 March.
Department of Geophysics, Johns Hopkins University, Baltimore. 9 May.
Research in our atmosphere and oceans. *Discussion with Professors E. B. Klaus and C. Rooth of the University of Miami. U.S.A. television.* 26 March.
Turbulence in stratified fluids. *Series of five lectures, the first at Louvain University and the remainder at Liège University, Belgium.* 19–25 May.
Mixing in the ocean. *NATO Summer School on Geophysical Fluid Dynamics, Bangor, North Wales.* 12 September.
Vertical mixing processes in the ocean. *International Symposium (57th Meeting of the International Council for the Exploration of the Sea) on Physical Variability in the North Atlantic, Dublin.* 25–28 September.
Intermittent turbulence in the atmosphere and ocean. *Seminar at Aeronautical Engineering Department, Imperial College, London.* 10 December.

APPENDIX III

PUBLICATIONS

The publications prepared by the Meteorological Office are generally issued by Her Majesty's Stationery Office as official publications. A complete list, with the prices at which they can be purchased through any of the sales offices or usual agents of Her Majesty's Stationery Office, is sent free to any applicant.

The following publications were issued during the period of this Report:

PERIODICAL

Annual Report on the Meteorological Office 1968.

Daily Aerological Record, containing information respecting meteorological conditions in the upper air over the British Isles to 21 December 1969.

Daily Weather Report, containing weather maps for the northern hemisphere, British Isles, etc., and data to 31 December 1969.

Daily Weather Report, Overseas Supplement, containing surface and upper air data to 30 June 1969.

Monthly Summary of the *Daily Weather Report* (to November 1969).

Monthly Weather Survey and Prospects, a monthly publication containing climatological data for Britain, the weather of the past month, a general survey and inference, and weather prospects for the coming month in Britain; a supplementary document, containing survey, inference and prospects only, is published in mid-month (to 31 December 1969).

Estimated Soil Moisture Deficit over Great Britain, a seasonal fortnightly publication providing estimates of soil moisture deficit in map form and as a tabular statement for river authority areas to 18 December 1969.

Meteorological Magazine (to December 1969).

Monthly Weather Report (to June 1969).

Marine Observer (quarterly) (to October 1969).

Seismological Bulletin. A diary of seismological disturbances recorded at Eskdalemuir, Dumfriesshire, on the standard American World-Wide Seismograph System together with observations from a short-period vertical seismograph at Kew Observatory to December 1968.

The Observatories' Year Book, comprising the geophysical results obtained from autographic records and eye observations at Lerwick, Eskdalemuir and Kew Observatories. 1966 and 1967.

OCCASIONAL

Observer's handbook, 3rd Edition, 1969.

Averages of earth temperature at depths of 30 *cm and* 122 *cm for the United Kingdom*, 1931–1960.

Marine observer's guide, 4th Edition, 1969.

Elementary meteorology for aircrew, 2nd Edition, 1969.

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